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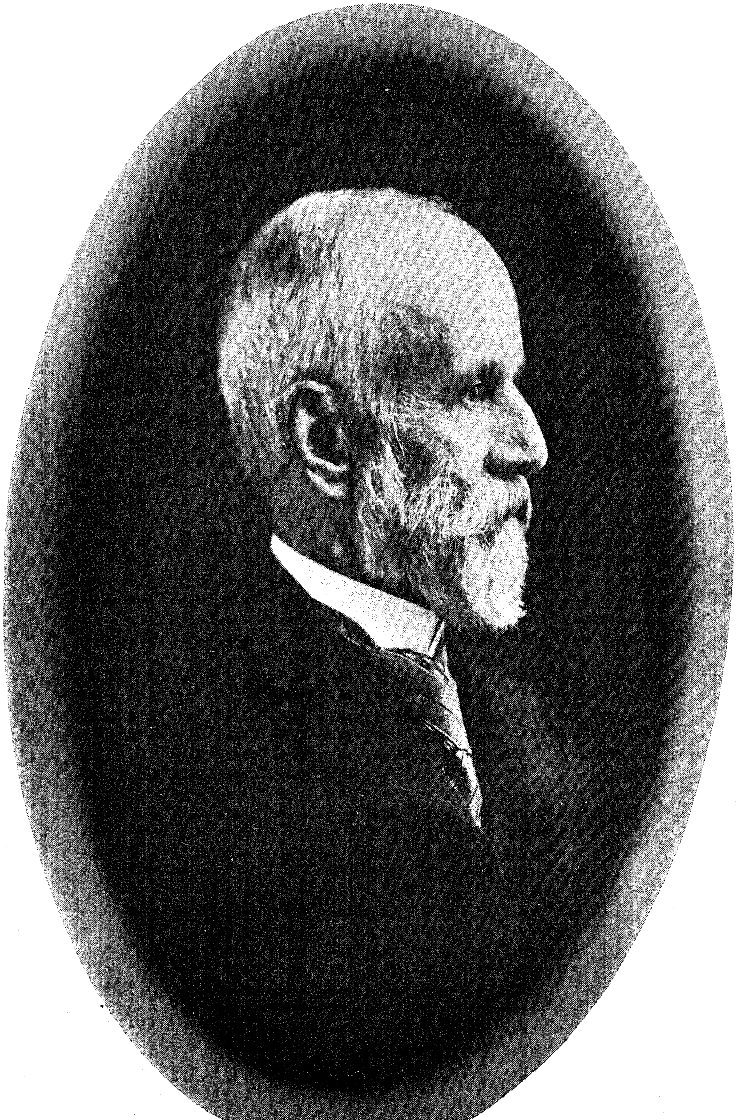

Henry L. Abbot

NATIONAL ACADEMY OF SCIENCES
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BIOGRAPHICAL MEMOIRS
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BIOGRAPHICAL MEMOIR

OF

HENRY LARCOM ABBOT
1831-1927

BY

CHARLES GREELEY ABBOT

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1929

HENRY LARCOM ABBOT
1831-1927

BY CHARLES GREELEY ABBOT

Chapter I

Ancestry

Henry Larcom Abbot, Brigadier General, Corps of Engineers, U. S. Army, member of the National Academy of Sciences, was born at Beverly, Essex County, Massachusetts, August 13, 1831. He died on October 1, 1927, at Cambridge, Massachusetts, aged 96 years. He traced his descent in the male line from George Abbot, said to be a native of Yorkshire, England, who settled at Andover, Massachusetts, in the year 1642. Through early intermarriage, this line is closely connected with that of the descendants of George Abbott of Rowley, Essex County, Massachusetts.

The Abbots of Andover were farmers, highly respected by their townsmen, and often intrusted with elective office in town, church, and school affairs. In the fifth generation, descended through John, eldest son of George Abbot of Andover,[1] Abiel Abbot, a great-grandfather of General Abbot, removed from Andover to settle in Wilton, Hillsborough County, New Hampshire, in the year 1763. He made his farm from the wilderness on "Abbot Hill" in the southern part of the township. Having cleared two acres and built a two-story house and barn, he married Dorcas Abbot and moved into the house with his bride before the doors were hung, in November, 1764. They had thirteen children, of whom the fourth, Ezra Abbot, born February 8, 1772, was grandfather to our propositus. Among other children were:

Reverend Abiel[2] Abbot of Peterborough, New Hampshire,

[1] The eminent family of authors, clergymen, and lawyers which includes Rev. Jacob Abbott, John S. C. Abbott, Rev. Lyman Abbott, Benjamin Vaughan Abbot, and others, descends through Nathaniel, twelfth child of George Abbot of Andover.

[2] Without vouching for the authority, which is that of a newspaper question corner, I venture to insert the following:
Q. Where is the oldest free public library in this country?
A. The town library of Peterborough, N. H., formed through the efforts of the Rev. Abiel Abbot in 1833, appears to have been the first free library which has continued to the present day.

of whom his grandson says that at ninety-three years old "he made it a point to read every day two chapters of the New Testament, critically, in the original Greek," and of whom a biographer says "it would be difficult to say what his faults in life were, he was so pure and upright in everything";

Reverend Jacob Abbot of Hampton Falls, New Hampshire, for many years a trustee of Phillips Exeter Academy and of the Adams Female Academy of Derry, New Hampshire;

Rhoda Abbot, who married Ephraim Peabody of Wilton, whose son, the Reverend Ephraim Peabody, was for eleven years pastor of King's Chapel, Boston, and whose granddaughter, Ellen Derby Peabody, married President Charles William Eliot of Harvard University;

Samuel Abbot, who, as a partner with his brother Ezra, invented the machinery for the manufacture of potato starch, in which they developed a large business;

Phebe Abbot, who married Ezra Abbot of Jackson, Maine, whose son Reverend Ezra Abbot of Cambridge, Massachusetts, attained so great distinction as a biblical student that the New York "Nation" says of him: "By the death of Ezra Abbot, the science of the New Testament criticism has lost one of the foremost scholars of this generation. . . . His loss is a national one, for no scholar ever shed more lustre on the American name."

Abiel Abbot was in continuous public service for the town of Wilton in many elective offices from 1765 to 1805. He was commissioned Captain, New Hampshire Royal Militia, in 1769, but later adhering to the Revolution, reached the rank of 1st Major in the New Hampshire continental militia. Though an officer, yet on emergency he enlisted as a private in a volunteer company of cavalry. He was always spoken of as "Major Abiel Abbot." He served sixteen years as a deacon of the Congregational Church.

Ezra Abbot, son of Major Abiel Abbot, succeeded to the ownership of the farm. He married, October 6, 1799, Rebekah, daughter of Lieutenant Joseph and Rebekah (Harris) Hale of Coventry, Connecticut. She was the niece of Captain

Nathan Hale, "the martyr spy of the Revolution." They had thirteen children, of whom the third, Joseph Hale Abbot, born September 25, 1802, was the father of General Abbot. The eighth child, Harris Abbot, born September 19, 1812, succeeded to the larger part of the farm on which his son, Stanley Harris Abbot, his grandson, Howard Stanley Abbot, and his great-grandson, Richard Hale Abbot, are now living.[8] The tenth, a son, Nelson Abbot, born November 17, 1816, inherited a smaller part of the farm, including the site of the original house, and his daughter Kate Abbot now resides there.

Ezra Abbot, like his father, was constantly engaged in town, school, and church business, serving in many elective offices for forty years. He was always spoken of as "Deacon Ezra Abbot." Becoming financially interested in the manufacture of potato starch for which his brother Samuel invented machinery, they built first a small mill on Deacon Abbot's farm, and later a larger one in connection with a water power about a mile distant in the town of Mason. Through the efforts of Ezra a considerable demand for the product as sizing was built up among the textile mills, so that, starting from nothing in the year 1813, they manufactured 23,000 pounds in 1820, and reached 238,500 pounds in 1829. The business was continued by Deacon Ezra Abbot and by his sons, Harris and Abiel, until about 1852.

Rebekah (Hale) Abbot, the wife of Deacon Ezra Abbot, was a very notable woman. She developed in all her children the love of reading and scholarly attainment. Her daughter, Abby Ann (Abbot) Rockwood, who also was a woman of remarkable character, has often spoken of the family custom of having one member read aloud for the edification of the others while engaged in household tasks. At his death, Deacon Ezra Abbot willed to his wife his library in addition to a sum of money and support during her lifetime from her son, Harris, who inherited the larger part of the farm. She survived her husband thirteen years, dying in 1860, aged 79 years.

[8] The author of this memoir, Charles Greeley Abbot, is the fourth child of Harris Abbot.

Reverend Edward Everett Hale, the eloquent preacher and gifted writer, was closely related to Mrs. Rebekah (Hale) Abbot, she being the niece, he the grand-nephew of Nathan Hale of Revolutionary fame.

Joseph Hale Abbot (1802-1873) father of General Henry Larcom Abbot, studied for college with Reverend Thomas Beede, minister at Wilton, expecting to enter Harvard College. But as accident would have it, a relative, Mr. John Abbott, called at the Abbot home with two sisters on the way to Brunswick, Maine. Having two chaises, another driver was needed, and it was decided that Joseph should go, attend Bowdoin College one year, and go to Cambridge later. He, however, remained and graduated at Bowdoin, standing near the head of his class. After taking graduate work at Harvard, he entered the teaching profession, which he followed with great success almost all of the remainder of his life, sometimes taking private pupils, sometimes teaching in public schools and academies.

Being exceedingly interested in natural philosophy, Professor Abbot was elected, in 1838, Resident Fellow of the American Academy of Arts and Sciences, which he served as secretary, 1850 to 1852. He published several articles on scientific subjects, including one in Silliman's Journal, October, 1840, describing original experiments and explaining the "Pneumatic Paradox" so called. In June, 1848, in Littell's Living Age and in the Atlantic Monthly of June, 1868, he contributed important articles on the controversy relating to the discovery and use of ether as an anesthetic. During the last fifteen years of his life he was laboriously preparing an original work embodying a lifetime of experience in the teaching and study of English grammar, but he did not live to complete it.

As a teacher he won the love, respect, even veneration of his pupils. Of his high character no truer record can be given than the words of his widow, who said: "Intellectual superiority and moral purity—these were the qualities I first required in my maiden ideal of a life companion; and, looking for these in your father, I was never disappointed."

Joseph Hale Abbot married, May 13, 1830, Fanny Ellingwood Larcom (1807-1883) of Beverly, Essex County, Massachusetts. She was the daughter of Captain Henry Larcom, and a granddaughter of Nathan Dane, LL. D., of the Continental Congress 1785-1788, framer of the famous "Ordinance of 1787" and founder of the Dane Professorship of Law at Harvard University.

Mrs. Abbot was a woman of rare charm and a brilliant conversationalist. The present author remembers her visits to his father's home as great occasions in his boyish mind. As in all New England farmsteads of that period it was customary not only for the family and visitors but the farm help as well to sit at table together. On one such occasion, the conversation in which Mrs. Joseph Hale Abbot was carrying her interesting part was much interrupted by a farm-hand named Jackson, who had seen war service, and had traveled with Barnum's circus. The unusual flow of wit spurred him to exalt his experiences which he dilated upon with what is called "the long bow." At last, to quiet him, Uncle Abiel Abbot turned suddenly upon him and said, "Jackson, did you ever see a Gyasticuticus?" Jackson hesitated but an instant and replied, "They had a big one in the circus—" but he got no further for the shout of laughter silenced him for the remainder of the meal, and left the conversation of "Aunt Fanny" its proper opportunity.

In the Atlantic Monthly for August, 1871, Mrs. Abbot published a thrilling account of the shipwreck of her father, Captain Henry Larcom. As it throws much light on the qualities of General Abbot's forbears and of the people they lived among, I quote freely from this account.

In the year 1809, under the First Empire, the French Government confiscated 29 American vessels lying in the harbor of Naples, and among them that which Captain Henry Larcom commanded. After long and fruitless attempts at release, through the efforts of the American consul one ship, with a crew of 15 and 31 passengers, comprising the captains and

others from the seized ships, was permitted to sail from Naples April 10, 1810, on her return home.

All went well till May 20, when, being ten days' sail from American ports, the vessel was capsized in a heavy wind, and the long-boat and yawl both damaged. After cutting away the masts the ship was righted, and one of the captains at great risk succeeded in mending with canvas and lead the hole in the bottom of the long-boat. The vessel's captain and crew got into it, partly provisioned it, took on all the tools, and, as it seemed to the others, in a heartless and cruel way abandoned the ship and left the thirty survivors to perish.

Captain Larcom and another were elected to command those left behind, and they succeeded in getting out food, and in building some protection on the after part of the ship. But heavy weather coming on, all their salvaging operations were stopped, their food was washed away, the vessel partly broken up, and only with great difficulty and danger did they save themselves on the forepart of the ship.

Having no water, fourteen died in one day from the effects of trying to quench their raging thirst with brandy. We continue in the words of Captain Henry Larcom and of Mrs. Fanny (Larcom) Abbot, recalling only that on June 6, 1810, there remained but fifteen of the survivors, of whom five were beyond hope, five preferred to run their chances on the ship, and five formed the company of Captain Larcom. He says:

" 'On the 6th of June the whole of the upper deck was gone, and everything that was between decks had floated out, leaving us without any subsistence, excepting some pork and beef, which it was impossible to eat for want of water. On the 7th of June, finding we could be of no use to those on the wreck, having nothing but brandy to subsist upon, and being then in lat. 39° 12′ N., thinking that too far south for the track of Europeans, we decided, five of us, to trust ourselves to the yawl, and endeavor to stretch northward.

" 'The morning we left the wreck we went under the bowsprit, and joined in prayer with Captain J—— for our deliver-

ance. At ten we bade them a final adieu, taking in the boat about two and one-half gallons of brandy and a little pork. . . .

" '. . . For sixteen days after we left the wreck we had no sustenance, excepting the brandy, of which we took a gill in the course of twenty-four hours. On the night of the 22d of June we had considerable rain, and we caught water enough, by holding up our handkerchiefs and wringing them, to quench our thirst partially, and to save two quarts. On the 23d T——, overcome with fatigue, hunger, and thirst, breathed his last, without a groan. On the same day we observed a number of rudder-fish round the boat, and making a dip-net out of a hoop and some twine, caught plenty, and, after drying them, we ate some of them, being the first food we had taken since leaving the wreck. From this time to the 27th we had several showers, and caught water sufficient nearly to quench our thirst; in which time I had eaten a small quantity of salt pork with some of the fish. But as soon as our water was gone I could eat no more. On the 28th of June L—— died of hunger, thirst, and fatigue. He went out of the world without a struggle or a groan. On the 29th, the boat still leaking so badly as to keep one man constantly baling, there being a heavy sea running, we had the misfortune to lose all our oars and the boat's mast. Having nothing left to steer the boat with, she lying in the trough of the sea, and being in great danger of filling every moment, we lost nearly all our remaining courage. However, we went to work to make a paddle to steer the boat with; by taking the yard from our boat's sail, which was made of the blade of an oar split in two, and seizing it together in its former place, and lashing a strip of board to it for a handle, by this means we kept the boat before the sea.

" 'On the 30th of June, about 3 P. M., the boat being half full of water, I was looking round between hope and despair, and, to my unspeakable joy, espied a sail to the southeast, which, after looking some time, I thought was standing from us. In about ten minutes I observed she was standing on the wind to the north-northwest, and that she would not fetch within two miles of us, we being to windward.

" 'We were now almost in despair, having neither oars nor boat's mast, and Mr. V—— so lame that he could scarcely move himself, but being in the stern of the boat, he took the paddle and kept her before the wind, while Mr. E—— baled the boat, which was leaking very badly. I went to work to rig a sail, and for that purpose took one of the boat's thwarts; and the Lord giving me strength for that effort,—I had very little natural strength left,—I split the thwart over the stern of the boat, seized it together, and made a mast six feet long; with a piece of board I made a yard; and in about ten minutes got a sail set, and was running before the wind to forelay the vessel. About four o'clock P. M., having run about two miles to leeward, we came alongside the vessel, which proved to be the General J—— of G——, from Lisbon, commanded by Captain S—— L. D——, who received us on board, and treated us with the tenderness of a brother while we remained with him. . . .' "

"My father lived fifty-two years after these events occurred, but he never could discuss them without an effort. Indeed, after he was eighty years of age, I have known him to lose a meal if this subject became a topic of conversation at table. . . .

"I remember hearing that, after the long-boat left them, my father was one day attempting to take an observation, when one of the men, suddenly becoming deranged, as several of them did before death ended their sufferings, rushed at him and knocked off his hat into the water. At this time the heat of the sun was very oppressive, and for a few hours he felt the loss very painfully; but at length it so happened that his own trunk, with the lid off, was 'washed up from the hold, and floated within reach.' It contained many valuable things carefully collected by him, but he said he thought only of securing something to protect his head. As it floated past him he caught at a bright-colored cashmere shawl lying upon the top; this he folded in a way to answer his purpose, and this he kept on his head until he was taken from the boat.

"I have this shawl in my possession now; faded with its exposure then to the sun and salt water, and stained where the

beloved head rested on the salt pork, which, when the parched mouths could no longer eat it, was used as a pillow in the boat. I have also a portion of a blue bandanna handkerchief which he held up to catch the precious drops of rain, and wrung into a small wooden box, with which they baled the boat, to slake his thirst. Of this handkerchief he finally made the 'signal,' which caught the eye of the sailor, who had been 'sent to the masthead to look out,' and who reported to Captain D—— upon the deck, 'I see a sail, sir, at a great distance,' and being ordered to 'look again,' shouted, 'it is something almost alongside now.' I have also a piece of tarred line, knotted at the ends, just twenty-one inches long, which was the exact measure of my father about his waist, taken carefully by Captain D—— the day he was received on board his vessel. He was a man rather above ordinary height, and of good proportions when in health. These, to me, precious relics I would have my children preserve after me, as tokens of suffering and privations so manfully borne more than half a century ago, by one who yet lived long enough to gain the love and veneration of them all. . . .

"The account given by Captain D——, of their appearance and condition when first rescued, I have often heard my mother repeat. This kind and good man, looking through his spyglass from the deck of the vessel, saw *nothing,* but, at the sailor's second report, the mate, looking over the side, saw, almost close to them, an indescribable object. So embrowned and emaciated were these men, almost divested of clothing, which had 'been used strip by strip to calk the boat,' that they had almost lost the semblance of humanity, as they lay,

'With throats unslaked,
With black lips baked,'

unable from debility and emotion to make audible replies to the questions proposed to them. My father attempted to rise and stand *upright* but in so doing lost his balance, and fell between the boat and vessel, but the mate, who was then preparing to leap down to them, caught him, as he touched the water, and

carefully passing a rope around his body, had him tenderly raised and placed safely on the deck of the vessel; and finally, after rescuing E—— in the same manner, the entire boat, with V—— lying in it, was hoisted on board the General J—— by the sympathizing sailors.

"Captain D—— said my father *'asked for nothing,* but at once seemed desirous to attempt *to give an account of himself,* which he did, in a hoarse whisper, but with a mind perfectly collected, and in a very direct and intelligible manner.' . . . I have heard my father say: 'I had *then* no hope of reaching home, and for twenty-four hours did not even inquire if the vessel were *homeward bound;* but I wished my friends to know my story, thanked God devoutly for giving me this chance of sending it to them, and thought, this being done, I could then lie down and die in peace, for I felt that I was *still at the gate of death.*'

"By Captain D——'s unceasing and extremely judicious kindness, however, they were surprisingly recovered in the twenty-one days they passed on board his vessel. . . . They anchored at G—— toward nightfall; and he was so desirous of going home *at once,* that Mr. L——, for many years a well-remembered driver of the stage-coach, then running only twice in a week between G—— and Boston, where several trains of cars now pass and repass daily, offered to drive him, in the most comfortable manner which could then be devised, to B——, and used years afterward to speak of it to the family as 'a peculiar privilege' that he had been allowed to do so. Strength, however, was not yet sufficiently restored to my father's wasted frame to enable him to perform at one effort the whole journey of fourteen miles; and about nine o'clock in the evening he was brought to his mother's house at W—— Beach, being still distant five miles from his own home, and was there received by her and her family 'as one arisen from the grave.' "

Meanwhile what of the home? Already the long-boat survivors had arrived and told their story. Of its effect we learn in Mrs. Abbot's words:

"It was a lovely June morning; its atmosphere comes back to me with all its balmy freshness; so does its midday heat, and its evening shadows; it is the first day I wholly remember.

. . .

"Presently a knock at the street door aroused my mother, and listening a few moments, she distinctly heard a lady who opened it say, 'do let her alone till evening!' 'No,' was a gentleman's reply, 'the children in the street would tell her before she could get ten rods from this door.' While they talked my mother descended the stairs, and with a face like marble, laying her hand firmly on Deacon L——'s arm, said in a strange, hollow voice, 'yes, tell me *now;* I can bear anything, if you do not say *he is dead!*'

"She was then quietly seated in an adjoining parlor, and very gently told that my father had taken passage in the ship M——, for S——, with thirty others, on the 10th of April; that on the 20th of May she had been wrecked in a squall within ten days' sail of home. That fifteen men—but he was not with them—escaped in the long-boat, had been taken up, and brought to Salem, having no hope that any other return could ever be made from the wreck.

"I had slipped into the room, and stood close beside my mother; I did not at all comprehend what had happened, but I was thrilled with the mournful quiet of the scene; and that room, with much of its furniture, and the faces in it, were so engraven on my memory in a few minutes, that though I never entered it again until one year ago, I found a distinct picture of it in my mind with which to compare its altered appearance. My mother uttered not one word, but suffered herself to be dressed and placed in a carriage, and with me seated beside her was driven home. This was about ten o'clock in the morning. She was placed in an easy-chair in her own chamber, where she sat nearly in one position, uttering no word or moan, nor in any way taking notice of the friends who passed in and out or gathered around her until about three o'clock in the afternoon.

. . . .

"At sunset her minister and very intimate friend, the good

J—— E——, who had been out of town all day, came in and sat down at her side.

"Being a man of strong sympathies, now deeply moved, he sat for some time, like the friends of Job, and 'spake no word, because he saw that her grief was very great.' Then as he afterward said, 'feeling that her condition was becoming dangerous,' he 'tried this experiment to arouse her.' Taking her hand, he said in a low, distinct voice: 'Sister L——, will you come to the church on Sunday and hear me offer prayer to God for you as a widow, and address the people?' She instantly startled him and all in the chamber by raising her tearless face and exclaiming, 'I have not yet heard that Henry is dead!' And when one near her whispered, 'Poor Child! she has gone crazy!' she added, almost cheerfully, 'God may have prepared a plank to save him, and he may be taken from some rock in the ocean.' And 'at that moment,' as she afterward often said, 'my first ray of hope dawned upon me.'

. . . .

"Toward the close of her term of sorrow, having once thrown herself down, as usual toward morning for rest, she dreamed that she was standing at a door of my grandmother's house, from which a wide view of the harbor could be seen; a heavy shower of rain was falling which suddenly ceased, and at once the setting sun lighted up the whole bay. Presently she discovered a plank, with three men upon it, approaching the land; while she looked it 'came ashore,' and the first man who leaped upon the beach was my father. She started to her feet, with a wide-awake assurance that he *was safè*. . . .

". . . In about a week after this time my father was brought to his mother's house, as you may remember, about nine o'clock in the evening. After the first shock of the arrival was over, it was my grandmother's first care to endeavor to have my mother and myself brought to them as soon as possible. And forgetting the hour, on a lonely road, my uncle's wife, with my eldest cousin, then a little girl, ran directly to the house of Captain M——, their nearest neighbor, who yet lived at a considerable distance; knowing that, as he owned a carriage, he would be only too happy to start immediately on this 'errand

of mercy.' Nor did they underrate his kindness. As soon as his chaise could be got in readiness, he set off at once, feeling, as he afterwards said, that he 'could consider what to do when he arrived, as he went along.'

". . . But unfortunately the door was opened to them by a well-meaning but injudicious woman, who acted in the capacity of a servant in the house; and while the gentlemen were communicating to one who followed her some of their facts, she rushed over those stairs, and before Mr. P——, who saw what she aimed at, could overtake her, she had seized the latch of my mother's chamber door, which was locked, and shaking it violently, shouted, 'Miss L——, Miss L——, get up. Your husband's down at the door, alive and well!'

"My poor mother had thrown herself face downward across the foot of her bed in a despairing mood a short time before, and thus had fallen into a troubled sleep. . . . She shrieked, and gathering the bed-cover in her hands, drew it tightly over her head, declaring afterward that, if she had heard that sound again, she must have instantly gone distracted. But in a moment the mild voice of Mr. P—— was heard, saying in a low, soothing, yet perfectly distinct tone, which fell on her ear 'like oil on the troubled waves,' 'No, no, dear. If you could presently open your door, here is Captain M——, who can tell you there is good reason to hope there is some real news of your husband.' This calmed her in an instant, *so much* she could bear to listen to; and in a little time, taking me on her lap, she was seated and quietly listening, while Captain M——, cautiously beginning with the fact that news had arrived of my father, after much suffering, having been taken on board a vessel from a small boat, gradually announced that the vessel was bound to G——, and at length, that it had arrived; that he had been taken to his mother's house that evening; and now, could she prepare herself and me to go to my grandmother's to meet him there?

"She listened like one in a dream, and at last said slowly and mournfully, 'Have you seen him? Are you sure he is living, and can live till I get there?' He replied, 'I have not myself seen him; your mother sent to me, and I came for you without

any delay; but I fully believe him to be living, though probably in a very exhausted condition; he sent for you to come to him.' . . . And now we go out into the open air, and are carefully placed in the chaise. It was near the middle of a hot night in July, and there was a very clear moonlight. . . .

"Not a word was spoken by any one until we came to that remarkable bend in the road, at the top of the hill near M—— Beach where the wide and beautiful ocean view bursts so suddenly upon the gaze; then my mother gently laid her hand on the reins, and said in an imploring tone, 'O Captain M——, do stop here, and turn your horse to carry me home! This *is only a dream;* it must be so; I cannot bear to go on!' With true tact, he instantly stopped the horse, and quietly settling himself into a posture for discussion, replied, 'I do not at all wonder at your doubts; I myself stopped my horse as I was going to your house, and it was just at this turn of the road too, and asked myself, "Am I not dreaming? Am I not on my way to excite hopes in that poor suffering young woman that cannot be realized?" Then I paused and reflected some time, and finally said to myself, "No, I cannot be mistaken; so many persons cannot all have been dreaming; our neighbor and her little niece certainly came to my house at a very late hour for them, and waking my wife and myself, told their story, and returned; then we called up our son, who harnessed the horse, my wife helping me to get ready; we could not all have dreamed."' Still he saw doubt resting on my mother's face; still humoring her mood, he said, 'I think we had better go on till we come toward "Sandy Way," where you know we can see your mother's house at a considerable distance; if it is lighted up at this hour, we will go on; if it is all dark, we will return.' To this she consented, though still unbelieving, saying not another word, until turning a corner they came in full view, though still at a distance, of the western end of the dear old homestead, illuminated even to the garret window. 'Then,' she afterward said, 'I felt assured.' And imagination busied itself, during the remainder of the ride, in picturing 'a wasted form, scarcely able to recognize her, bolstered up in the bed, which it would never again quit alive.' As the chaise drove up the ample green

yard to the front door, my father stood at it, extending his arms to his wife and child. As they received me, my mother fell senseless to the ground, before any one could prevent her fall.

. . . .

"We remained a few days at W—— Beach, until my father felt able to return to our own home. Even here . . . for weeks after his return, my mother said that, though he carefully avoided all voluntary allusion to the subject during the day, yet at night, as soon as his eyes were closed in sleep, he would startle her with such ejaculations as 'For God's sake, hail the boat, E——!'

"In after life I often heard persons say to him, 'How could you ever dare to trust yourself at sea again?' To which he would reply, 'I felt ten times more confidence than ever, after being rescued from such dangers.'

"And so it was that, in six months after his return, he sailed for the West Indies."

To Joseph Hale and Fanny E. (Larcom) Abbot was born in Beverly, August 13, 1831, the eldest of seven children, Henry Larcom Abbot. Other progeny of Joseph Hale and Fanny (Larcom) Abbot also showed good parts. The other children were:

Edwin Hale Abbot, 1834-1927
Francis Ellingwood Abbot, 1836-1893
Emily Frances (Abbot) Vaughan, 1839-1899
Captain Edward Stanley Abbot, born 1841, mortally wounded at Gettysburg, July 2, 1863, while leading his company near Little Round Top.
Son, born and died 1844.
William Fitzhale Abbot, 1853-1922

Edwin Hale Abbot, late of Cambridge, Massachusetts; A. M., 1858, and LL.B., 1861, of Harvard University; practiced law in Boston, Milwaukee, and New York; was President of the Wisconsin Central Railway, and director of other railway corporations. He was a man of wide reading and culture as well as of

great business success. His elder son, Philip Stanley Abbot, A.M., LL.B., 1867-1896, was a man of exceptional charm, who took high honors in all activities, social, athletic, and scholastic at Harvard University, but being an expert mountain climber lost his life untimely in the attempted first ascent of Mount Lefroy, Alberta, Canada. The younger son, Edwin Hale Abbot, A.M., LL.B., 1881-——, is an eminent lawyer.

Francis Ellingwood Abbot, late of Cambridge, Massachusetts, A.M., Ph.D. Harvard, graduated from Meadville (Pennsylvania) Theological School. His researches in philosophy and religion were very profound. Editor of "The Index," 1870-1880, he later taught private pupils and published numerous philosophical articles, and especially two books, the embodiment of his system, entitled "Scientific Theism" (1885), and "The Way Out of Agnosticism" (1890). Of his seven children but three reached adult years. One, Edward Stanley Abbot, A.M., M.D. Harvard, is an eminent specialist in mental diseases.

Emily Frances Abbot married Abiel Abbot Vaughan, a merchant of Cambridge, Massachusetts. She was active in social and church enterprises, and a fine amateur water-color artist.

William Fitzhale Abbot was an able teacher, who for many years had charge of the college preparatory department of the Worcester (Massachusetts) High School. He was Secretary of the American Antiquarian Society, 1885-1891.

Such was the ancestry and immediate family of General Abbot. In his own countenance and character shone out the quiet scholarly life. Though not in the least lacking in social charm, he went little in society, preferring the study, where throughout his life he engaged in research after research, and in the preparation of papers, giving both to the technical and the lay public the results of his investigations. Medium in height and weight, he measured about 5 feet 7 inches, and weighed in health approximately 170 pounds. Considering the following table, his longevity may well be regarded as an inheritance.

Name	*Age at Death*	*Relation to Propositus*
Henry L. Abbot	96	Propositus
Joseph H. Abbot	71	Father
Fanny E. L. Abbot	76	Mother
Henry Larcom	85	Grandfather
Ezra Abbot	75	Grandfather
Rebekah H. Abbot	79	Grandmother
Abiel Abbot	68	Great-grandfather
Dorcas Abbot	85	Great-grandmother
John Abbot	89	Great-great-grandfather
Phebe F. Abbot	90	Great-great-grandmother

Average 83.4 years

Chapter 2

Early Life. Pacific Survey

In the fortunate circle of a happy family of moderate means, shared with a sister and several brothers; frequently spending an active out-of-doors summer at the ancestral Wilton homestead, Henry L. Abbot passed his perfectly normal childhood and youth. He left the Boston Latin School shortly before graduation in order to accept appointment to the U. S. Military Academy at West Point. Entering as a cadet July 1, 1850, he graduated, standing number two in his class, June, 1854.

This high standing, of course, entitled Abbot to ask service in the Corps of Engineers, but under the mistaken notion that their assignments would keep him in the old, well-settled portions of the country, he applied for the Artillery which at that time was largely on western frontier posts. Fortunately his mistake was corrected by two curious coincidences. Being invited to spend the week after graduation on the estate of Professor H. R. Agnel, Cadet Abbot happened to meet there, while tramping in the forest, a West Point graduate of the

class of 1853. This young lieutenant inquired of Abbot which branch of service he would enter, and expressed surprise that with such high standing he had passed over the opportunity to join the Engineers. Learning the reason, he strongly advised a reconsideration, informing Abbot that the Topographical Engineers were at that very time engaged in pioneering surveys for railroads in the far West and were thus afforded the best of opportunities to see remote parts of the country.

Young Abbot regretted his choice, but feared it would make a bad impression to start his military career by asking a change of assignment. However, shortly afterward, and again by accident, he met on a hotel piazza the Adjutant of the Academy, Fitz John Porter, afterwards a corps commander of the Army of the Potomac, who said: "Abbot, I notice that you have not applied for the Engineers, though your rank entitles you to do so. I have not yet mailed the applications, and if you should wish to write a new one I will tear up the original." They went directly into the hotel office, and young Abbot made out on hotel paper an application for the Topographical Engineers. By this curious series of happenings his whole career was altered.

He soon received the following order:

"Office Pacific Surveys. Washington, May 1, 1855.

"SIR: By direction of the Secretary of War [then Jefferson Davis], you will report to Lieut. R. S. Williamson, Topographical Engineers, for duty on the explorations and surveys in California and Oregon, with which he is charged.

"It is understood that you are second in rank of the party, and that, if sickness or any accident should disable Lieutenant Williamson, so as to oblige him to relinquish the command, you will succeed to the charge and command of the party.

"Very respectfully, your obedient servant,

"A. A. HUMPHREYS,
"Captain Corps Top. Engineers,
"In charge of office for Pacific
"Railroad Survey.

"Lieut. Henry L. Abbot,
"Corps Topographical Engineers."

So much of their assignment as they were destined to finish is included in the following excerpt from Secretary Davis' order of May 1, 1855, to Lieutenant Williamson:

"1. To make such explorations and surveys as will determine the practicability, or otherwise, of connecting the Sacramento valley in California, with the Columbia river, Oregon Territory, by a railroad either by the Willamette valley, or (if this route should prove to be impracticable) by the valley of the Des Chutes river, near the foot slopes of the Cascade chain. Along Des Chutes river the character of the country is such as to render it improbable that a practicable route can be found."

Owing to the illness of Lieutenant Williamson, it fell to Lieutenant Abbot to prepare and transmit the report of their survey, which he did, with the promptness and thoroughness which ever characterized him, under date of May 6, 1857. The report, comprising 499 quarto pages, forms Volume 6 of "Explorations and Surveys for the Pacific Railroad." Of this volume, Part 1 and the Appendices are by Lieutenant Abbot, comprising 198 pages, the remainder on the geology, botany, and zoology of the region was contributed by the civilian assistants under his direction.

On May 5, 1855, Lieutenants Williamson and Abbot, with their civilian assistants sailed from New York, crossed the Isthmus of Panama (much later to be the scene of General Abbot's celebrated researches relating to the Panama Canal), and arrived at San Francisco, May 30. Organizing his party there, Lieutenant Williamson was in camp at Benicia ready to commence work on July 9, 1855.

The party included five civilian technical assistants, a pack master with large mule train in charge of eighteen packers, mostly Mexican. Later, when arrived at the dangerous Indian country, the expedition was reinforced by a military detail of eighty foot and twenty dragoons under command of Lieutenant H. G. Gibson, with Lieutenants George Crook and J. B. Hood, and additional packers and guides. Lieutenant Hood being later ordered to Washington, he was relieved by Lieutenant P. H. Sheridan. The reader will notice among the

small number of responsible names of those connected with this expedition the future President of the Southern Confederacy, and several general officers in high commands on one side or the other in the great Civil War, so soon to follow.

Although about to survey a mountain wilderness, known to be filled with a tangle of precipices, deep canyons, and fallen trees, and traversing a volcanic region almost impassably obstructed with soft and hard ejecta, the expedition took with it one light cart to carry the barometers, sextants, chronometers and other instruments, but primarily to serve as an odometer to measure distances. The narrative has frequent references to the "little cart," how it overturned and broke some of the instruments; or how after all the instruments were removed it took the united force to let the "little cart" down some precipice; and how the body of the "little cart" was finally totally smashed, but the wheels were kept and still retained the title. Finally, while lifting the wheels over an endless succession of fallen trees, in crossing the Cascade Mountains by a little-used pass near Mount Hood, the Indian guide said that if they were to reach water by sundown they must "mam-uk mam-a-loos-ten-as chik'-chik," which means, being interpreted, "kill the little cart." Lieutenant Abbot adds: "I also decided much against my will, to 'kill the little cart.' The men took the spokes for picket pins, and in this form our old friend continued to accompany us to the end of the journey."

Great care was taken to measure altitudes and latitudes. Owing to the disabling of the chronometers in one of the adventures of the "little cart," the observers were early prevented from determining longitude by time differences. This defect they remedied as far as possible by taking many bearings of the numerous high peaks of the region, so that their map is in close accord with modern surveys. Lieutenant Abbot devotes a whole chapter to the description of his means of correcting and reducing barometric readings for altitude, and shows by a long tabular comparison with actual levels that the results of his barometric method have a mean error of but 9 feet. Here we see a good example of that passion for precision that distinguished his work throughout his life.

After following up the Sacramento valley for a considerable distance, the expedition crossed over the Cascade range, and struggled on among lava beds, precipices, fallen trees, past the Klamath lakes to the upper canyon of the Des Chutes river. Here Lieutenant Williamson with the dragoons under Lieutenant Sheridan attempted to find a practicable pass over into the Willamette valley, while Lieutenant Abbot pushed on to the Columbia river and returned with supplies. Lieutenant Williamson then crossed over to the coast and returned by sea to San Francisco to prepare for the remainder of the survey, leaving Lieutenant Abbot to come down overland on the west side of the Cascade range.

Just after this separation of the party, a fierce Indian uprising broke out, so that the greatest doubt prevailed as to whether the party could be extricated at all. Settlers fled to the larger places and many families were murdered. Fortunately Lieutenant Abbot had been told by a half-breed of a rarely used pass south of Mount Hood. He was fortunate, through his own pleasant relations with the Indians and a working knowledge of their language, and also through the good offices of one of the last of the settlers to flee to safety, in getting the good-will of a chief called Kok-kop. Although he did not himself know the pass, this chief assigned to the party a young Indian named Sam An-ax-shat who had once been through the pass. This was perhaps the last friendly act of Kok-kop or of Sam, but the latter with complete fidelity piloted the party through the often perfectly indistinguishable trail to the valley of the Willamette, recovered for them a mule that had strayed with valuable cargo, and then decamped in the night in fear of his life from the white settlers.

To show more vividly the character of this march, I quote from Lieutenant Abbot's diary of October 10 to October 14, 1855:

"October 10.—This morning the weather was clear. We started early, abandoning a horse that could travel no further. On leaving camp we ascended a steep hill about 400 feet high, and then gradually descended, for about a mile and a half, by

a succession of pitches connected by narrow terraces. They conducted to a small brook, flowing north through a ravine destitute of grass. Continuing a southerly course for about two miles further, we found ourselves in a small dry prairie, where the trail suddenly seemed to disappear. Thus far to-day we had been very little troubled by fallen timber. Our guide dismounted, and, directed by signs too slight for our eyes, led us across the open spot to a place where the Indians had blazed the trees for a few rods into the forest, but where no trail on the ground was visible. We had before occasionally seen blazing, and sometimes twigs broken in the direction of the trail. The blazing generally consisted of a simple cut, laying bare the wood; but sometimes we found a rude image of a man marked in the bark. This always indicated that much fallen timber was to be expected. The object of the blazing, in the present instance, was simply to indicate a direction, for it soon ceased, and even Sam could see no trail. By carefully preserving the course it had pointed out, however, he led us about a mile up a gentle slope, covered with much fallen timber, to the brink of an enormous precipice, which seemed vertical. There was a trail near the edge, which conducted us up a gradual ascent to the foot of a very steep mountain, composed of basalt and compact metamorphic slate, whose summit was bare of trees. After climbing it with much labor, and the loss of a mule that rolled down the precipitous side, a magnificent panoràma burst upon our view. At an elevation of 5,000 feet above the sea, we stood upon the summit of the pass.[4] For days we had been struggling blindly through dense forests, but now the surrounding country lay spread out before us for more than a hundred miles. The five grand snow peaks, Mount St. Helens, Mount Rainier, Mount Adams, Mount Hood, and Mount Jefferson, rose majestically above a rolling sea of dark, fir-covered ridges, some of which the approaching winter had already begun to mark with white. A yawning ravine, into which we had gradually and unconsciously descended this morning, came from the north, near

[4] This is the summit by my trail. It is 500 feet higher than that of the proposed wagon road.

Mount Hood, and winding to the south round the mountain on which we stood was lost in the dim distance. Another, heading near us, wound out of sight towards the west. On every side, as far as the eye could reach, terrific convulsions of nature had recorded their fury, and not even a thread of blue smoke from the camp fire of a wandering savage, disturbed the solitude of the scene.

"Near this mountain we noticed an extraordinary local variation of the magnetic needle, which numerous bearings to well-known peaks enabled me to measure with considerable accuracy. At places about two miles from the mountain, both before reaching and after leaving it, the variation, as usual in this region, was about 18° east. At the top of the great precipice encountered about a mile before reaching the mountain, it was only 11° east, while on the summit it was 16° west. The needle was thus actually disturbed 34° by some abnormal cause. It, however, settled readily. The mountain was principally composed of slate and basalt, like those around it, and we could see no indication of iron or other local cause of disturbance in the vicinity.

"During the remainder of the day's march, the trail followed a knife-like ridge between two great cañons east and west of us, to avoid the fallen timber in them, and it was very mountainous in its character. After a steep descent we toiled up another peak, two miles distant from the first and very similar to it. From the summit we could look many miles down the great westerly ravine, and distinctly see the blue hills of the Willamette valley beyond its mouth. This peak was separated from the next one of the ridge by a cañon connecting the two great ravines. This we crossed with difficulty, and continued to follow the narrow ridge, toiling up and down several more steep peaks rising from it, until the sun was only a few minutes high. Some of our exhausted animals were far behind, and the Indian said that we were still a long way from the 'Stone House,' where he had expected to encamp. He knew, however, a spring not far off, where we could get water, but no grass. We reached it on the steep eastern side of the

ridge just as the sun set. Its bed was dry. We were all feverish from fatigue and thirst, and it was a bitter disappointment; still, to advance was impossible, and our animals were unpacked and tied to the trees as they gradually came in. Two had broken down entirely, and been abandoned on the way. In the meantime the Indian had disappeared. When he returned he quietly remarked that he had discovered water. We rushed to it, and found a little spring which flowed almost drop by drop from under a rock in the thick bushes. There was enough for the men, but none for most of the suffering animals, and their cries from hunger and thirst were incessant through the night.

"October 11.—This morning we took a westerly course, which led us over the ridge that we had been following, into a third great ravine heading near us and winding out of sight to the northwest. The descent was about seven hundred feet, and very abrupt. In the ravine we found a fine stream of water and a small lake, bordered by some good grass, which, however, had been eaten so short by Indian horses that our animals could get none. This place Sam called the 'Stone House.' The origin of its name I could not discover, but probably there is a cave in the vicinity. It is a great Indian whortleberry camp, and we found the bushes still loaded with berries. The lake is doubtless the source of a branch of Sandy river. Disappointed in not finding grass for the animals, we toiled up a steep precipice of compact slate, 1,000 feet in height, to the summit of the western side of the ravine, and obtained an extended view of the surrounding country. On every side nothing could be seen but fir-clad ridges and frightful cañons; most of our animals were on the point of giving out from fatigue and hunger; and, to crown our misfortunes, Sam quietly informed me that he had only travelled between the 'Stone House' and Willamette valley once, and that was when he was a child. He had a vague recollection of many mountains and a great scarcity of grass on the way. Under these happy auspices we pushed desperately on towards the west. After following a narrow ridge thinly covered with trees, until we had travelled a little more than six miles from

camp, we fortunately found a small opening in which the ground was wet from numerous springs and thinly dotted with grass We had hardly encamped, when a rain storm that had been threatening all the morning, suddenly burst upon us, causing great anxiety lest it should change into snow Sam and I explored the vicinity on foot, and I was fortunate enough to obtain a good bearing to Mount Hood through the clouds It was N 40° E We were on a narrow ridge, with an immense cañon on each side of us, and the supply of grass was very limited The number of whortleberries was so great that we could strip them from the bushes by handfuls

"October 12—All last night and today, a cold and steady rain poured down, chilling our animals and rendering the trail slippery and dangerous Although I greatly feared snow I decided to remain in camp and recruit the animals, as many must have given out had we proceeded To eke out their scanty supply of grass, I issued a small quantity of hard bread, which most of them ate eagerly We collected heaps of pine knots and logs in different parts of the opening, in order to pack the mules by fire-light on the following morning, and thus get a very early start In the night it cleared off, and Mr Anderson and I left our beds, and obtained good observations for latitude

"October 13—We had reveille at two o'clock this morning, and started as soon as it was light enough to see the trail It followed a continuous ridge, varied by a succession of steep peaks, slippery from the rain After slowly climbing over them for about three miles, we encountered one so steep that the ascent seemed impossible We, however, carefully urged the animals along a narrow ledge, which wound up the face of the tremendous precipice, and at length gained the summit The blue Willamette valley, marked by a line of fog rising from the river, lay below us, and the word 'settlements,' shouted down the line, inspired every one with new life From this point we began a rapid descent to the level of the valley At the foot of the mountain there was a small grassy swamp around which the trail wound in nearly a semi-circle Beyond

it we crossed a rocky pedregal, and then followed another ridge less mountainous than the former one. It gradually disappeared, and left us among thick fallen timber. A very few clumps of bunch grass again began to appear among the trees. This trail had been used by the Indians of the Willamette valley to reach the whortleberry patches, and they had cut through many of the logs. Still vast numbers were left, and we were obliged, in several places, to clear a path with axes. We slowly worked our way on, in this manner, until night overtook us, and compelled us to encamp in the dense forest without either water or grass. During the night the cries of the half starved animals were very distressing. We also suffered much ourselves from thirst, which a diet of musty hard bread did not tend to allay.

"October 14.—Yesterday, one of our best mules, with a valuable pack, was lost on the way, and I sent two men back this morning to search for him. The fallen timber diminished in quantity as we advanced, and the trail soon became excellent. Pressing rapidly forward we reached, about five miles from camp, a little log cabin on the edge of the forest, and, with a feeling of inexpressible satisfaction, found ourselves at last in the long wished for Willamette valley."

Though the War Department orders had specified a military escort of one hundred men, the commander of the forces in Oregon felt justified, owing to the exigency of the Indian uprising, in withdrawing the escort completely. Both Lieutenant Williamson and Lieutenant Abbot strongly urged the danger to the expedition and to its valuable records, but without being able to modify the commanding officer's decision. Hence, Lieutenant Abbot was obliged to march south through the hotbed of the Indian warfare with his train of 120 animals and 30 men, mostly unarmed civilians and Mexican packers. Fortunately he was able to follow for a considerable distance through the mountains a small detachment of volunteer militia, but he was forced to forego several side surveys which were necessary to fully accomplish his investigation. En route, the expedition passed by burned cabins and the bodies

of slaughtered settlers, and narrowly missed the scene of a fierce battle, but reached the headwaters of the Sacramento without loss.

Lieutenant Abbot's report points out the prohibitive expense of constructing a railroad through northern Oregon on the eastern side of the Cascades, although the eastern route was found practicable as far north as the Klamath lakes. On the western side of the Cascades he considers it practicable to follow the Willamette and its coast fork from the Columbia river, a distance of about 150 miles; thence by Pass creek, a branch of the Umpqua river, and across a small divide to Elk creek and up over Long's hills; thence following the path of his expedition to the North Umpqua river at Winchester and the route surveyed, or some small variation of it to Canyonville, some 60 miles farther. The Umpqua mountains would then be found a formidable obstacle, and he regrets that the lack of escort prevented him from more thorough explorations here. Yet he thinks the road practicable either through the Umpqua or the Cow Creek canyon though at considerable expense.

From the southern base of the Umpqua mountains to Wolf creek no serious obstacle was found, but from thence to Rogue river the route followed by his party was very unfavorable. He again regrets that he was forced by lack of escort to forego further exploration, but gives information he gathered as to alternatives, which on the whole seem practicable. Thence to the foot of the Siskiyou mountains on Stewart creek no great obstacles would be encountered.

But now the great obstacle of the Siskiyou mountains is encountered, and he admits that no practicable route over them was surveyed by his party. He thinks it might have been practicable, had the escort been available, to have found a route through the Cascade mountains to join the surveyed route east of them, and thus avoid great difficulties. On the other hand, his inquiries led him to think that some variations of his own route through the Siskiyou mountains might be found, leading

to the Klamath river, and thence to Yreka. From Yreka to the middle reaches of the Sacramento river he suggests several practicable routes, of which he inclines to prefer one striking the head-waters of the Sacramento river west of Mount Shasta, and thence following the course of the stream. He concludes by quoting a report on a preliminary survey of this route for a wagon road, as made by several local gentlemen.

It speaks well for the keenness of observation of this young lieutenant engaged on his first assignment, that the Southern Pacific railroad now follows exactly the course he recommends from Redding, California, all the way to the mouth of the Willamette near Portland, Oregon. On the other hand, only recently has a railroad been constructed north of the Klamath lakes on the eastern side of the Cascade range which he found impracticable.

Chapter 3

The Control of the Mississippi

The National Academy of Sciences was not organized until 1863. General Abbot owed his election to it in 1872 to the remarkable investigations which he made as a young man in his twenties, in the years 1857 to 1860, in cooperation with General (then Captain) A. A. Humphreys on the flow and control of the Mississippi river. Their report, originally printed as Professional Papers of the Corps of Topographical Engineers, No. 4, 1861, and reprinted as No. 13 of the Professional Papers of the Corps of Engineers, 1876, is a classic in river hydraulics. Although seventy years have elapsed, it is still very highly regarded, although naturally some modifications would now be made, both as regards measurements and theory. It is mainly since the comparatively recent establishment of hydraulic laboratories abroad—a move which our own country is very late in following—that new principles useful to the control of streams are being added to the sterling results of this research.

It is difficult to give an adequate idea of the comprehensive character of this extraordinary investigation. The geographical and geological conditions of the vast basin of the Mississippi and all its important tributaries are extensively described. The history of river hydraulics in the old as well as the new world is summarized, and the principal ideas and investigations of leading scientists as to the flow of rivers are critically examined. New methods of measuring cross sections and velocities of flow of streams are worked out with careful attention to the elimination of errors. Abundant observations of these quantities are made under all conditions of flood at numerous points on the Mississippi and its tributaries. Formulæ are deduced which accurately represent all these data. The histories of many crevasses in the levees during high floods, with determinations of their flow and the effect they produced on the flow of the main river, are traced. Changes in the bed of the river as influenced by levees, outlets, cut-offs, and the other modifications of the banks which are practicable in river control are quantitatively determined. The practicability and exact effect of all suggested means of flood protection are carefully examined, and mathematically derived directions are given to show what is necessary and sufficient as protection against any flood which history warns us to forecast. The clearance of the delta for navigation is considered in the same quantitative manner. In short, the authors aimed to accept no assumptions, but to satisfy every inquiry by exact measurements made under such a wide variety of conditions as to enable them to reduce the whole subject to accurate mathematical expression, so that estimates could be based with certainty thereon.

In order to supplement authoritatively this inadequate picture of what was attempted, I quote extensively from Captain Humphrey's letter of transmittal. Yet even this fails to give the impression of complete study of a tremendous problem which comes only from the full perusal of the great report itself.

"Office of the Mississippi Delta Survey,
"Washington, August 5, 1861.

"Major Hartman Bache,
"Corps of Topographical Engineers,
"In Charge of Bureau of Topographical Engineers,
"War Department, Washington.

"SIR: Under the act of Congress directing the Topographical and Hydrographical Survey of the Delta of the Mississippi river, with such Investigations as might lead to determine the most Practicable Plan for securing it from Inundation, a Board, consisting of Lieutenant-Colonel S. H. Long, Topographical Engineers, and myself, was organized in November, 1850, and directed to examine the river with a view to decide upon the character and extent of the surveys required. It was further ordered that, the duty of the Board being completed and a report thereon being made, I should take the direction of the work.

"In accordance with those instructions, the report of the Board was made from Napoleon, Arkansas, December 18, 1850. That report was communicated to Congress and printed in Senate Ex. Doc. No. 13, 31st Congress, 2d session. The field of survey and investigation by measurement, as enlarged by authority of the Bureau of Topographical Engineers in the following spring, extended from the head of the alluvial region at Cape Girardeau to the Gulf of Mexico. At a still later date, the investigations were authorized to include within their scope the best mode of deepening the channels at the mouths of the river, an object which had been likewise contemplated in the original appropriation act.

"That act required a topographical and hydrographical survey of the delta of the Mississippi to be made in connection with the investigations; and in execution of the plan of operations laid down in the report of the Board of December, 1850, three parties were at once organized to determine the topography, hydrography, and hydrometry of the alluvial region. Fortunately for the objects of the Survey, the succeeding high water proved to be a flood of a peculiar character.

"The topographical party in charge of Mr. James K. Ford, assisted by Mr. Joseph Bennett, Mr. W. Thornton Thompson, Mr. George F. Fuller, and Mr. Samuel Hill, made a minute topographical survey of the Mississippi river, extending from one mile above Routh's point to one mile below the Barataria-canal locks, just above New Orleans, collecting at the same time information concerning the crevasses of former years, old flood-marks, the history of levee construction, the dimensions of levees, well authenticated changes in the banks of the river, etc., etc. Owing to the high stage of the river, and the consequent inaccessibility of the east bank between the foot of the Raccourci cut-off and a point one mile above Baton Rouge, that portion was omitted. The survey included the mouth of the Red river, the heads of bayous Atchafalaya, Plaquemine, and La Fourche, and numerous off-set lines—among them one from Carrollton to the mouth of the new canal, lake Pontchartrain. . . .

"The hydrographical . . . operations included the measurement of sets of cross-sections of the Mississippi at Routh's point, at Red river landing, in the Raccourci cut-off, at Raccourci bend, at Baton Rouge, at site of Bonnet-Carré crevasse, at Carrollton and above and below that locality, and of sets of cross-sections of the mouth of Red river, of Old-Red river bend, and of the heads of bayous Atchafalaya, Plaquemine, and La Fourche. In each set of cross-sections, the velocity of the current was measured—in some instances, with great elaboration. The nature of the material pushed along at the bottom of the river was examined from time to time. . . .

". . . Gauge-rods were established in lakes Pontchartrain and Borgne, in the gulf bayou at Fort St. Philip, and—in the river—at Fort St. Philip, Carrollton, Donaldsonville, Baton Rouge, Red river landing, Natchez, New Carthage, and Lake Providence. Most of these observations were continued for two years, and some of them longer. The gauge-observations made under the Navy Department at the Memphis Navy Yard were relied upon for that position, and private gauge-observations at Napoleon and Cairo for those localities. Temporary gauge-rods were likewise observed at Berwick's bay, at Field's

Mills on bayou La Fourche, and at Indian Village on bayou Plaquemine.

"The chief labor of the hydrometrical party, however, was directed to the constant measurement of the velocity of the current of the Mississippi in all parts of the width and depth of the Carrollton section, in order to obtain the volume of discharge in every condition of the river throughout the period of a river year; and with a view to determine the law of change of velocity from the surface to the bottom, and from side to side; including the effect of wind; and thus to furnish the hydrometrical data for completing the determination of the laws governing the flow of water in natural channels. During a portion of the periods of high and low water, similar measurements were made upon a section of the river at Baton Rouge, in which vicinity the course of the river is nearly straight for several miles.

"In connection with these operations, the amount of sedimentary matter held in suspension by the river was measured daily for two years, together with the temperature of the river-water, and the air, etc. The character of the material pushed along the bottom was likewise examined from time to time.

"Detachments from this party measured the discharge of the crevasses in the vicinity of Carrollton, the cross-sections of Berwick's bay, and of the La Fourche, at Pain Court, Thibodeaux, and Field's Mills, and ran a line of levels from the high-water mark of the Mississippi, at McMaster's plantation, to the gauge-rod at Proctorsville on lake Borgne. Mr. Smith's lines of cross-section, at Carrollton, were likewise re-sounded by this party in low water, 1851.

"It also made experiments upon the velocities of the current from the surface to the bottom at the mouths of the Mississippi, both in the high and low states of the river, sounded the bars, and determined by measurement the advance of that of the Southwest pass.

"The results of the labors of all these parties enter into the most important deductions of the report; they will be found

embodied in the chapters devoted to the subjects for which they were designed to furnish the data.

. . . .

"While engaged in the field, in the summer of 1851, I was suddenly prostrated by sickness, which obliged me early in the following winter to relinquish the charge of the work to Lieutenant-Colonel Long, Topographical Engineers. The operations in the field were soon after entirely suspended, with the exception already stated in connection with the Carrollton work, and continued so until the fall of 1857, when, the charge of the work having been previously resumed by me, the surveys and investigations were again vigorously prosecuted.

"During the interval, while they were in abeyance, the state of my health still rendering me unfit for duty, I sought and obtained authority to visit Europe, with instructions to examine its delta rivers, and ascertain what the experience of many centuries had really proved as to the ultimate as well as immediate effects of the different methods of protection against inundation. Such of the results of that visit as have immediate application to the Mississippi river are briefly embodied in the text of the Report.

"Upon returning from Europe, in the summer of 1854, I was assigned to special service under the immediate orders of the War Department, and placed in charge of the Office organized in connection with the Explorations and Surveys, then in progress, for the determination of the most practicable and economical route for a railroad from the Mississippi river to the Pacific ocean. The duties thus devolved upon me prevented my giving sufficient attention to the Survey of the Delta of the Mississippi to admit of its active resumption until the autumn of 1857.

"At my request, Lieutenant Henry L. Abbot, Topographical Engineers, was then directed to report to me for duty on the Delta Survey. This request was made in order that Lieutenant Abbot might take the immediate charge of the parties of the Delta Survey under my direction, the office being estab-

lished at this place. An arrangement of this kind was rendered absolutely necessary by the nature of the duties then imposed upon me. . . .

"Previous to the resumption of the field work of the Survey, Lieutenant Abbot recomputed the volumes of discharge at Carrollton from the original notes. . . .

"As other important duties required my presence in Washington at that time, Lieutenant Abbot was directed by me in November, 1857, to proceed to the Mississippi river, organize the necessary parties, and prosecute the surveys and investigations. The completion of the Topographical and Hydrographical Survey of the Delta in the manner in which it was commenced in 1851 was not attempted; because the Investigations, the more important of the two classes of work called for by the appropriation acts, required the expenditure of the balance of the appropriation. It was extremely fortunate that they were resumed just at that time, for the flood of 1858 was one of a remarkable character, and furnished data which could not have been collected if the appropriation had been exhausted by the resumption of the Survey in a previous year, inasmuch as no Mississippi flood occurred between 1851 and 1858.

"In compliance with these instructions, gauge-rods were established at Columbus, Kentucky; Memphis, Tennessee; Napoleon, Arkansas; Vicksburg, and Natchez, Mississippi; and Red river landing and Carrollton, Louisiana. Donaldsonville, Louisiana, and Cairo, Illinois, were subsequently added to the list. A daily record of the height of the water upon the rod, the state of the weather, the direction and force of the wind, etc., was kept at these stations until January, 1859. The observations at Columbus, Memphis, and Vicksburg were continued until September, 1859, and those at Carrollton until April 30, 1861. From May 11, 1859, to June 5, 1860, a self-registering tide-gauge was maintained at the mouth of the Southwest pass, a portion of the corresponding Carrollton observations also being made with one of these instruments.

"A party . . . established at Columbus, Kentucky, 20 miles below the mouth of the Ohio, . . . measured daily the velocity of the current from bank to bank, and occasionally

from surface to bottom. To this duty were added the determination of the quantity of earthy matter held in suspension by the river-water, and a careful survey of the river above and below the base of current-observations, with lines of level to determine the slope of the river at high and low water. A survey across the low grounds between Cape Girardeau and the Commerce bluffs was likewise made by this party.

"A party with similar duties . . . was stationed at Natchez, Mississippi, but was subsequently moved to Vicksburg, Mississippi, . . . In addition to its regular duty of current-measurements, this party made a careful survey of the river for about eight miles at Vicksburg, including the site of the velocity sections, with exceedingly accurate lines of level to determine the slope of the water surface at various stages between high and low water, entirely around the abrupt bend above Vicksburg. The discharge of the Yazoo river was also measured by this party, whenever it could be done without interfering with the regular progress of the work of the Vicksburg station. . . .

"The observations at Columbus were continued until November 16, 1858, and those at Vicksburg until December 15, 1858. The summer of 1858 was remarkable for its intense heat and sickly character, notwithstanding which, the gentlemen composing these parties never relaxed their exertions.

"Similar but much less elaborate observations were made . . . to ascertain the daily discharge of the Arkansas river at Napoleon. These commenced on January 1, and continued until November 30, 1858.

"Aided by Mr. Pattison, and, at times, by others of the assistants . . . Lieutenant Abbot, besides establishing the parties at Columbus and Natchez, measured accurate cross-sections with corresponding velocities, of the following streams, to determine approximately their discharge during the flood; the Ohio, the Hatchee, the St. Francis, the White, the Arkansas, the cut-off between the Arkansas and White rivers, the Yazoo, the Red, the Black, the Atchafalaya bayou, Old river above Red-river landing, and Grand river at Berwick's bay, Louisiana. In addition, accurate measurements of the high-

water cross-sections of the Mississippi were made by him at Columbus, Kentucky; New Madrid, Missouri; a point two miles above Osceola, Arkansas; Randolph, Tennessee; Helena, Arkansas; Napoleon, Arkansas; Lake Providence, Louisiana; Vicksburg, Mississippi; New Carthage, Louisiana; Natchez, Mississippi; Baton Rouge, Louisiana; Bonnet-Carré, Louisiana, and Fort St. Philip, Louisiana.

"Mr. Pattison, assisted by Mr. J. D. Julian, measured in 1859 similar sections on the lines of survey of 1851 above and below the site of the Bonnet-Carré crevasse, and on two of those at Carrollton, Louisiana. He likewise re-sounded the bayous Plaquemine and La Fourche, on the lines of 1851, with some additions; and re-surveyed the heads of these bayous and of bayou Atchafalaya with a view to detect any changes which might have occurred since 1851.

"Aided by Mr. W. H. Williams, Lieutenant Abbot measured with great care the discharge of the Bell crevasse near New Orleans in May, 1858, and thus, in connection with the observations made by the parties in 1851, obtained the elements necessary to frame rules for ascertaining the discharge of crevasses. The locality of this crevasse and that of the La Branche were surveyed with minute accuracy by Mr. W. H. Williams during the following low water.

"As soon as the flood of 1858 subsided, a party . . . passed down the Mississippi, from Cairo to the mouth of Red river, in a yawl, measuring the dimensions of the various crevasses occasioned by that flood, and collecting all the information regarding date of occurrence, rate of increase, etc. . . .

"Great care was taken to obtain from every available source correct information respecting the dimensions, condition, and extent of the levees throughout the alluvial region, the history of their progress, etc.; respecting the height and date of the floods throughout the same region; the depth of overflow in the swamps bordering the river, the nature of the growth upon them and their geological character; and the seasons and dates of the floods, the range, etc., of the tributaries of the Mississippi.

"The intelligent and energetic labors of Lieutenant Abbot, faithfully aided by the gentlemen [of the party] accomplished a great amount of work.

"Series of detailed observations upon the currents at and near the bar of the Southwest pass, from the surface to the bottom, were made. . . .

"Various circumstances successively delayed my intended inspection of the operations in progress on the Mississippi in 1858, and the examination of particular localities, until the month of May. A short time after my arrival in Louisiana, a return of my former illness, induced by the excessive heat of the climate, rendered me unable to perform, without great suffering, any duty for the remainder of the summer.

"In the fall of 1859, measurements similar to those made at the permanent hydrometric stations of Carrollton, etc., were made upon a canal feeder of the Chesapeake and Ohio canal, at the Little Falls of the Potomac, by Lieutenant Abbot, assisted by Mr. Pattison and Mr. Vaughan, with a view to determine the laws governing variations in certain coefficients entering the new formulæ derived from the Mississippi observations.

"To complete the Delta Survey, every source from which reliable information connected with the question of Mississippi floods could be collected was examined. Wherever a record of the rise and fall of the Mississippi and its tributaries has been made, it was secured if possible.

. . . .

"As the surveys and investigations progressed, the great labor commenced of reducing the observations, of assembling the results, of combining and digesting them, of the development of the laws governing all the phenomena that were subjects of examination, and, finally, of the application of these laws to the solution of the great problem which formed the object of the Delta Survey.

"This work, which was in fact the preparation of the Report, was performed by myself and Lieutenant Abbot. It involved an amount of labor and study, which will not perhaps be fully appreciated even by professional persons. Devoted to the task,

Lieutenant Abbot brought to its performance great industry, energy, sagacity, and skill in analysis, the fruits of which, to be found in every part of the Report, are particularly exhibited by the chapters in which the flow of water in natural channels is treated. But a perusal of the Report will convey a more forcible impression of the extent and value of Lieutenant Abbot's labors than any terms of acknowledgment that I can use. In the mass of exceedingly intricate calculation necessarily attendant upon such a work, Lieutenant Abbot has been aided by Mr. F. W. Vaughan, a skilful computer, whose zeal, unwearied care, and industry in the performance of the duties he was employed upon, entitle him to more than the ordinary terms of acknowledgment.

"Some reference to the state of the question of protection against inundation, at the time when the Survey of the Mississippi Delta was begun, appears to be proper here, in order that the necessity of such extended and laborious investigations as were made may be appreciated, and that it may be understood how absolutely essential it was in every division of the subject to collect fact upon fact, until the assemblage of all revealed what were and what would be the true conditions of the river in every stage that it had passed through or could attain, and thus to substitute observed facts and the laws connecting them for assumed or imperfectly observed data and theoretical speculations.

"A wide discretion was necessarily entrusted to the officer in charge of the Mississippi Delta Survey. I entered upon the execution of that duty with an apprehension that the laws of flowing water in natural channels as enunciated in treatises upon the hydraulics of rivers, were not based upon sufficiently extended experiments upon natural streams, and, hence, that the formulæ found in them could not be relied upon for the solution of the questions upon which the plans of protection against inundation from overflow depended. The system of measurements and investigations carried on at Carrollton, Louisiana, Vicksburg, Mississippi, and Columbus, Kentucky, while it was intended to render the solution of the problem of the protection of the alluvial region of the Mississippi

against inundation independent of the laws and formulæ of the books, was at the same time designed, in connection with other parts of the survey, to afford the means of determining, by experiments on a far more extended scale than any ever before attempted, the laws governing the flow of water in natural channels, and of expressing them in formulæ that could be safely and readily used in practical applications. The success that has attended this part of the work has even exceeded my expectations. Laws have been revealed that were before unknown, new formulæ have been prepared, possessing far greater precision than the old; and improved methods of gauging streams have been devised.

"But the imperfect state of the science of hydraulics as applied to rivers was not the only difficulty to be encountered in the execution of the duty imposed upon the officer in charge of this work. The much-agitated question of the best method of protection against inundation had been always discussed upon assumed data, and the truth of the very ground-work upon which these discussions rested had to be experimentally investigated by this Survey. For instance, the Mississippi had always been regarded as flowing through a channel excavated in the alluvial soil formed by the deposition of its own sedimentary matter. So important an assumption was inadmissible; and great pains were accordingly taken to collect specimens of the bed wherever soundings were made, and by every means to ascertain the depth of the alluvial soil from Cape Girardeau to the gulf. This investigation has resulted in proving that the bed of the Mississippi is not formed in alluvial soil, but in a stiff tenacious clay of an older geological formation than the alluvion, and that the sides of the channel do not consist of homogeneous material; facts that have an important bearing upon all plans of protection.

"Further, it was held by the advocates of the exclusive use of artificial embankments that the levees of Louisiana had already lowered the bed and floods of the Mississippi river, and that their extension throughout the alluvial region above would still further lower the floods by deepening the bed and reducing the slope of the river. The advocates of outlets, on

the contrary, contended that the experience of many centuries, on the Po, proved that levees had raised the bed and floods of that river—to such an extent, indeed, that it was impracticable any longer to protect the country, except by opening new channels to the sea. This conclusion appeared to be sustained on the authority of two distinguished names, Cuvier and de Prony. While the investigations of the Delta Survey have rendered untenable that position of the advocates of the exclusive use of levees on the one hand, the investigations of the Chevalier Elia Lombardini have shown the supposed facts advanced by the latter class to be entirely erroneous, and their apprehensions to be unfounded.

"The effects of cut-offs were likewise the subjects of controversy among engineers, a controversy which the measurements of the Delta Survey must set at rest, since they demonstrate that cut-offs raise the floods below them, a conclusion sustained by the well-established effects of such works upon the Po and Adige.

"Outlets were advocated by some engineers because they were considered a ready and inexpensive means of reducing the floods. On the contrary, they were objected to by others because, as they claimed, outlets would raise the bed and floods of the river. The investigations of the Delta Survey prove that outlets, in the few localities where they are practicable, may be made to reduce the floods to any desired extent in certain divisions of the river; but that they would not be inexpensive, and would entail dangers and disasters which should not be risked. These conclusions, it is shown are sanctioned by the experience of Europe upon the Po, the Rhine, and the Vistula.

"The effect of a great swamp like that of the Yazoo upon the floods of the Mississippi, a subject that has formed the theme of speculation for at least thirty years, has also been established by the collection of facts; as likewise the law governing the rise, fall, and discharge of the river throughout the alluvial region; the manner in which the flood is propagated; the modifications introduced by tributaries; the succession of river stages; the drainage of its basin and that of its tribu-

taries; the proportion of drainage to downfall, and the discharge of outlets: in fact, every river phenomenon has been experimentally investigated and elucidated.

"Thus every important fact connected with the various physical conditions of the river and the laws uniting them being ascertained, the great problem of protection against inundation was solved.

"At the mouths of the river, a similar course has resulted in the development of the law under which the bars are formed, the depth upon them maintained, and the regular advance into the gulf continued; and, as a consequence, the principles upon which plans for deepening the channels over them should be based, and the best mode of applying them. The rate at which the river progresses into the gulf, and the extent, thickness, and relative level of the alluvial formation having been ascertained, its probable age has been estimated; and the ancient form of the coast, and the changes that have taken place in the present geological age, have been surmised.

"The Report exhibits in detail the investigation of each of these subjects, and many others not enumerated in this letter. Based upon extended survey and investigation in the field, made at times under circumstances of great exposure, it contains the results of many years' labor, comprising laborious office work, extended research, patient investigation, and exhaustive mental effort. The association of Lieutenant Abbot with me in this duty has been of such a character that the title of the Report should bear his name as well as mine. I beg leave therefore to submit it herewith to the Bureau of Topographical Engineers, as our joint Report upon the Survey of the Delta of the Mississippi river.

"Very respectfully, your obedient servant,

"A. A. HUMPHREYS,

"Captain Topographical Engineers, U. S. Army."

As remarked above, the investigations were highly comprehensive. The authors sum up their recommendations in the matter of the protection of the Mississippi valley in the following paragraphs:

"The preceding discussion of the different plans of protection has been so elaborate and the conclusions adopted have been so well established, that little remains to be said under the head of recommendations. It has been demonstrated that no advantage can be derived either from diverting tributaries or constructing reservoirs, and that the plans of cut-offs, and of new or enlarged outlets to the gulf, are too costly and too dangerous to be attempted. The plan of levees, on the contrary, which has always recommended itself by its simplicity and its direct repayment of investments, may be relied upon for protecting all the alluvial bottom lands liable to inundation below Cape Girardeau. The works, it is true, will be extensive and costly, and will exact much more unity of action than has thus far been attained. The recent legislation of Mississippi in organizing a judicious State system of operations, however, shows that the necessity of more concert is beginning to be understood. When each of the other States adopts a similar plan, and all unite in a general system so far as may be requisite for the perfection of each part, the alluvial valley of the Mississippi may be protected against inundation.

"To secure this end in the most economical manner, the operations of this Survey indicate that levees should be constructed. Near the mouth of the Ohio, they should be made about 3 feet above the actual high-water level of 1858, which has been selected as the plane of reference, because more unvarying than the surface of the ground. The height above this level should be gradually increased to about 7 feet at Osceola. Thence to Helena, the latter height should be maintained. Thence to Island 71, the height should be gradually increased to 10 feet. Thence to the vicinity of Napoleon, it may be gradually reduced to 8 feet. Thence to Lake Providence, it must be gradually increased to 11 feet. Thence to the mouth of the Yazoo, it may be gradually reduced to about 6 feet, and should be thus maintained to Red-river landing. Between that locality and Baton Rouge, it should be kept uniformly about 4 feet, and below Baton Rouge about 3 feet. If the water-mark of 1858 be unknown at any locality, it may be re-

duced to any well-determined local mark by the table in Chapter II. The above estimate is exclusive of settling, and allows about a foot for possible rise above the height necessary for restraining the flood of 1858.

"It should be remarked that these heights are based upon the supposition of *absolute security,* so far as its conditions can be ascertained. . . .

"It will be noticed that near Lake Providence the levees must be constructed of enormous height to restrain the floods. It may, therefore, be well to reduce them by constructing, near that town, an outlet leading to bayou Tensas and Black river. Its capacity should not exceed 100,000 cubic feet per second, a volume which might be made to pass off through the natural drains of the Tensas swamp without producing serious inundation. Those drains have always discharged a large amount of crevasse-water in the great flood years, and may be depended upon for sensibly relieving the river in that vicinity. Abstracting 100,000 cubic feet per second at that point would reduce the river flood three feet throughout that part of the region between Napoleon and Vicksburg which it is most difficult to protect, and would thus materially reduce the cost of the levees and the danger of crevasses. Before undertaking the project, however, extensive borings should be made to ascertain the character of the substrata. Unless a solid bed of clay should be found at a moderate depth, the outlet should not be undertaken, lest it might become too large for the safety of the region bordering upon bayou Tensas and Black river. Under any circumstances, it would be an injury rather than a benefit, to the country below Red-river landing (see discussion of flood of 1851), and in the event of coincident floods in the Mississippi and Red rivers, it would be disastrous to the lower part of the Tensas and to the Black river country."

While their solution of this important problem has not proved to be quite so absolute as Humphreys and Abbot very reasonably believed it to be, they laid a foundation on which

others may build up the complete edifice, correcting those faulty details which by the very completeness of this great pioneer work have come to test the sooner.

Chapter 4

Civil War Service and Subsequent Military Career

The great task of the preparation and printing of the Mississippi river report was still occupying Lieutenant Abbot when the Civil War broke out in 1861. He managed to drive the book through the press in season to take part in the first battle of Bull Run, where he was seriously wounded, and brevetted captain for "gallant and meritorious services." Soon recovering from his wound, he was continuously in service and rapidly promoted so that at the age of thirty-three years he commanded a brigade of troops in the field. A summary of his Civil War record and subsequent military assignments follows:

Chronology, Henry L. Abbot

June, 1850-June, 1854: Cadet, West Point.

Class standing: January, 1851, No. 1; June, 1851, No. 3; June, 1852, No. 4; June, 1853, No. 2; June, 1854, No. 2.

Cadet appointments: Corporal, sergeant, lieutenant.

July 1, 1854: Bvt. 2nd Lieut., Topographical Engineers, U. S. Army.

Oct. 12, 1854-May 19, 1857: Surveys for Pacific Railroad in Oregon and California.

Oct. 2, 1855: 2nd Lieut., Topographical Engineers, U. S. Army.

May 19, 1857-July 1, 1861: Survey Delta of Mississippi River.

July 1, 1857: 1st Lieutenant, Topographical Engineers, U. S. Army.

Civil War Service.

July 5-15, 1861: Topographical Engineer, Staff of General McDowell.

July, 1861: Chief Engineer, Tyler's Division in Manassas Campaign.

July 18, 1861: In action of Blackburn's Ford.

July 21, 1861: In action at Bull Run, seriously wounded; bvt. Captain for meritorious service at Battle of Bull Run.

July 23-Aug. 21, 1861: On staff of General McDowell, defenses of Washington.

Aug. 21, 1861-Mar. 10, 1862: Assistant to Gen. Barnard.

Mar. 10-July 24, 1862: Aide-de-camp to Gen. Barnard during Peninsular Campaign.

Apr. 5-May 4, 1862: In action Siege of Yorktown.

June 18, 1862: Captain, Topographical Engineers, U. S. Army.

June 26-July 2, 1862: In action in seven days' operations before Richmond.

July 24-Sept. 25, 1862: Sick leave, Chickahominy fever.

Sept. 25-Nov. 11, 1862: Aide-de-camp to General Barnard fortifying approaches to Alexandria, Va.

Nov. 11, 1862-Feb. 10, 1863: Chief Engineer, Banks expedition to the Gulf.

Jan. 19, 1863: Colonel of Volunteers commanding 1st Conn. Heavy Artillery.

Mar. 3, 1863: Captain, Corps of Engineers, U. S. Army.

Feb. 28, 1863-May 10, 1864: Command of regiment and brigade south of Washington.

Jan. 27-May 31, 1864: Member of Board revising system Coast Defense of U. S.

May 13-June 23, 1864: Command of Siege Artillery, Army of the James.

June 23, 1864-Jan. 5, 1865: Command of Siege Artillery of armies operating against Richmond.

July 30, 1864: Personally served in Mine Assault.

Aug. 1, 1864: Bvt. Brig. General, U. S. Volunteers for gallant and meritorious services in the operations before Richmond, and especially in the lines before Petersburg, Va.

Jan. 5-22, 1865: Chief of Artillery of expedition against Fort Fisher, N. C.

Jan. 22-July 13, 1865: Command of Siege Artillery of Armies operating against Richmond.

Mar. 13, 1865: Bvt. Lieut. Colonel, U. S. Army, for gallant and meritorious services during the Siege of Petersburg.

Mar. 13, 1865: Bvt. Colonel U. S. Army, for gallant and meritorious services during the Rebellion.

Mar. 13, 1865: Bvt. Maj. General U. S. Volunteers, for gallant and meritorious services during the Rebellion.

Mar. 25, 1865: Personally served in battle of Fort Steadman.

Apr. 2, 1865: Personally served in assault on Confederate intrenchments.

May 10-July 13, 1865: Chief of Engineers, Department of Virginia.

July 15-Sept. 25, 1865: Command of the Brigade in defenses of Washington.

Sept. 25, 1865: Mustered out of volunteer service.

Oct. 4-Nov. 23, 1865: Awaiting orders.

Nov. 11, 1865: Major, Corps of Engineers, U. S. Army.

Nov. 25-Dec. 12, 1865: Command Engineer Battalion, and constructing Fort Schuyler, N. Y.

Dec. 12, 1865-May 29, 1866: Assistant Engineer examining Mississippi levees.

June 1, 1866-March 15, 1886: Command Engineer Battalion and Engineer School at Willets Point; also Command of General Engineer Depots, and constructing Fort Schuyler, N. Y.

Sept. 11, 1866-May 18, 1867: Member of Board on use of iron in permanent defenses.

June 12, 1868-May 24, 1886: Constructing fort at Willets Point, N. Y.

Dec. 19, 1868-Nov. 15, 1869: Member of Board to revise Ponton Manual.

May 5, 1869-Aug. 13, 1895: Member of New York Board of Engineers for Fortifications.

June, 1869: Member of Board on Wallabout Channel to N. Y. Navy Yard.

Oct. 7, 1870-Jan. 20, 1871: On detached service under Secretary of the Treasury to observe solar eclipse in Sicily.

July 2-Oct. 13, 1873: On professional detail to learn all possible about the torpedo systems in Great Britain, Germany, Austria, and France, and to contract for large mileage of torpedo cable in London.

July 2, 1874-Jan. 18, 1875: Member of Board of Commissioners to devise a plan to reclaim the Mississippi River alluvial basin.

Feb., 1875: Member of Board on proposed Topolobambo Railroad in Mexico.

Apr. 5-June 13, 1877: Member of Board to examine contracts between United States and Moline Water Power Co.

June 1, 1879: Member of Board of Visitors to West Point Military Academy.

Mar. 31, 1880: Lieutenant Colonel Corps of Engineers, U. S. Army.

Apr. 3, 1883-Dec. 20, 1884: Member of Gun Foundry Board.

Apr. 10, 1886-Aug. 13, 1895: Drilling Engineer troops in Torpedo service.

Oct. 12, 1886: Colonel, Corps of Engineers, U. S. Army.

Oct. 25, 1888-Aug. 13, 1895: Member of Board of Ordnance and Fortifications.

Mar. 12, 1885-July 27, 1888: Member of Endicott Board to select sites for seaboard fortifications.

Aug. 13, 1886-Aug. 13, 1895: Member Boston Harbor Line Board.

Oct. 5, 1888-Aug. 13, 1895: Member of New York City Harbor Line Board.

Dec. 3, 1888-Aug. 13, 1895: Division Engineer North East Division.

Aug. 13, 1895: Retired for age.

Engagements After Retirement.

1895: Chairman Jury of Higher Awards, Atlanta Exposition.

1895-1896: Consulting Engineer Manitowoc harbor for Wisconsin Central Railroad.

1895-1896: President, Board on Lake Erie-Ohio River Ship Canal.

1895-1918: Member Board of Overseers, Thayer School of Engineering.

1896-1897: Member of Forestry Commission.

March 23, 1897-1900: Member of Comité technique de la Cie. Nouvelle du Canal de Panama. Living in Paris.

Feb. 1898-Feb. 1899: Member of Comité statutaire of same Company. In Paris.

Feb. 1899-May, 1904: Consulting Engineer of same Company. Living in the United States.

Apr. 23, 1904: Brig. General U. S. Army, Retired.

June, 1905-Feb. 1906: Member of Roosevelt Board of Consulting Engineers to report on type of canal.

May 1905-June 1910: Professor of Hydraulic Engineering, George Washington University.

Dec. 7, 1915-Jan. 1916: Member of Commission on slides in Culebra cut, visiting the Isthmus.

Shortly after the Civil War closed, General Abbot, then as always devoted to scientific aspects, prepared a paper entitled "Siege Artillery in the Campaign Against Richmond," which was published as No. 14 of the Professional Papers of the Corps of Engineers. In the Introduction he says:

"The rapid progress made of late in the science of artillery demands close attention from the Corps of Engineers. Indeed any facts bearing upon the capabilities, uses, and theory of modern ordnance possess an interest almost as great for engineers as for artillery officers. For these reasons I have devoted such time during the past year as my professional duties would allow, to preparing the following memoir, designed to place in a small space the most important results of the recent experience in Virginia. Incidentally, an analysis of the

problem of ricochet firing upon water has been attempted, based upon certain data collected before my volunteer command was disbanded at the end of the war.

. . . .

"The important batteries of siege guns in all these campaigns were served by the 1st regiment of Connecticut artillery, which was thus identified in a conspicuous manner with the history of the army of the Potomac. This paper is therefore in some sort a record of its labors, and especially of its contributions to the science of artillery.

Record of First Connecticut Artillery

"In May, 1861, this regiment was mustered into the United States service as infantry. On January 1st, 1862, it was changed to artillery. After a few months of drilling in the defenses of Washington, it went into the field under Colonel Tyler to serve the siege train of 1862. It there took rank as one of the best disciplined and most efficient regiments in the army, and became imbued with a spirit of enthusiasm for the duties of its special arm.

"In January, 1863, after the promotion of Colonel Tyler, his Excellency W. A. Buckingham, Governor of Connecticut, conferred upon me (then captain of engineers, United States army) the appointment of colonel of the regiment. From that date until its muster out of service in September, 1865, it remained under my command; constituting the basis of an artillery brigade which sometimes exceeded an aggregate of 3,500 men.

. . . .

"With a wise appreciation of the requirements of a good military organization, his excellency Governor Buckingham uniformly appointed its officers from the regiment, and never except upon the recommendation of its commanding officer. It is hardly possible to overstate the advantages conferred by this system. The *matériel*, like that of most of the volunteer regiments, was of an unusually good character; college graduates being by no means unknown to its ranks, while the majority were possessed of a good common-school education.

"The commanding officer had thus in his power, by making just and judicious recommendations to the governor, to offer to the members of the regiment a career open to merit, uninfluenced by political or other favoritism; and to secure to himself the aid of a body of officers in every way qualified for their duties. This was naturally considered a matter of primary importance; and whenever a few vacancies had occurred the following system was adopted in selecting the nominees. Each captain was called upon for the name of his non-commissioned officer best entitled by acquirements, character, and faithful performance of duty to receive a commission. Field officers added those personally known to themselves to the list, which thus usually contained from twenty to thirty names. An examining board, consisting of all the field officers, including the commanding officer, was then convened, and the candidates were thoroughly examined in artillery and infantry. All the non-commissioned officers were habitually required to recite to their company officers in the textbooks treating of those branches whenever the duties of the regiment would allow; and these examinations were consequently thorough, exceeding half an hour to each candidate. After carefully comparing his own notes of the examination with the lists of the other field-officers, due weight being given to the character of the candidate for soldierly qualities and energetic performance of duty, the commanding officer submitted his recommendations to his excellency the governor.

"At every promotion, up to captain inclusive, the senior in each grade passed a similar examination before the same board, so that if an unworthy appointment had been made no subsequent promotion would be obtained.

"The power of assignment and of transfer among the different companies being vested entirely in the hands of the regimental commander, he was enabled to promote non-commissioned officers into companies where they were strangers to the enlisted men; to give to officers failing in one company an opportunity of benefiting in another by their past experience; and to see that each company contained officers well qualified

for all varieties of duty. Great attention was always paid to this matter, which was judged to be of vital importance.

"The character of the officers of the regiment can be inferred from the method of their appointment. The jarring factions so common to most volunteer regiments were nearly unknown to the 1st Connecticut artillery. Its officers were a body of men who appreciated the dignity of their position, and who were well educated in their duties. The regimental record shows how those duties were performed."[5]

He then takes up the subject of mortars as follows:

"After a little experience in campaigning in Virginia, both armies adopted the expedient of immediately intrenching themselves upon taking up a position. This was chiefly caused by the murderous precision of the rifled small-arms with which both armies were supplied, but was also very useful in covering the troops from horizontal artillery fire. The rapidity was surprising with which the 'rifle pits,' so called, could be thrown up by the aid of a few axes for felling timber, and shovels, or even bayonets or tin cups in cases of necessity, for moving dirt. After a few hours' work, the men lay secure in their trenches, indifferent alike to artillery and musketry fire. Vertical fire alone could severely annoy them.

"Although at the siege of Yorktown we had placed heavy mortars in position, and had practically experienced the annoyance of receiving upon our approaches the constant fire of one 8-inch mortar from the Confederate lines, neither belligerent availed itself during the subsequent campaigns of this species of artillery, prior to the advance of the army of the Potomac from the Rapidan, in the spring of 1864. In preparing for this campaign, General Hunt, chief of artillery, had procured eight Coehorn mortars to accompany the movement, and had included in the composition of my siege train many 10-inch and 8-inch siege mortars and Coehorns. It was a new arm to the

[5] "The following extract from a letter from General Barry, dated July 27, 1865, speaks for itself:

" 'As chief of artillery successively of the two principal armies of the United States during the four years of war now happily ended, I have enjoyed unusual opportunities for observation. You will on this account value my opinion when I assure you that the 1st Connecticut artillery, in intelligence and the acquirements and services of its special arm, stands unrivalled in the armies of the United States.' "

troops, and excited much interest and attention from both officers and men. Owing to the peculiar character of the march from the Rapidan to Petersburg, but little use was made of the Coehorns; although they were placed in position and served on the lines at Cold Harbor. After the failure of the first assault upon the Confederate position on the heights of Petersburg, the siege train was called into active service, and then began for the first time in the experience of the armies operating in Virginia, a really heavy mortar fire.

"Having noticed the effect upon the morale of our troops produced by the indifferent practice of the single 8-inch mortar from the Confederate lines of Yorktown, I had paid great attention to training the gunners in the use of this arm while in the defences of Washington. They were familiar with all the minor but essential details upon which the effect of vertical fire depends; and, as I learned at the time from deserters, and subsequently from Confederate officers, the result of their sudden and unexpected opening on the Petersburg lines was appalling. Having no mortars wherewith to reply, and no bomb-proofs for cover, and yet being compelled by the proximity of the main lines (only two hundred yards distant in the nearest place) to keep their own fully manned in order to guard against an assault, the enemy suffered severely for the first few days, and the moral effect was extremely depressing. On one occasion which came under my personal observation, a Confederate soldier was blown entirely over his parapet by the explosion of one of our shells; and his body lay, the clothing consumed by fire, beyond the reach of his friends who were deterred from approaching by our sharpshooters. To thus deprive an opponent of the accustomed protection of the trenches is well calculated to shake his nerves preparatory to an assault, or to retard or prevent the pushing of siege approaches.

"As soon as the enemy could obtain mortars they placed them in position, and from that time until the evacuation the fire was frequent and severe on several points of the lines. Our expenditures amounted to over forty thousand rounds, and theirs were not much less. Having the benefit of previous

training, our gunners retained the advantage, and the precision of their practice was justly admired.

"Mortars were first introduced and multiplied upon the Petersburg front, with a view to preparing the way for an assault, and for keeping the artillery of the enemy quiet when it was delivered. This purpose they accomplished most effectually. When, after the Mine fiasco, the project of directly assaulting the Confederate position was abandoned, the fire was maintained to keep down picket firing and to compel the silence of certain very annoying batteries, which from the left bank of the Appomattox river, enfiladed the right of our line and caused much loss. Both parties ultimately constructed bomb-proofs, and remaining as much as possible under cover when the firing was going on, received little injury. For this reason it was gradually discontinued on this part of the line.

"At Dutch Gap, however, the Confederates had an opportunity to reap the full advantage of vertical fire, and they continued it there until the canal was essentially completed, sinking one of the dredges and greatly harassing our working parties. They placed their mortars in sunken batteries, provided with good bomb-proof cover, on the low ground on the right bank of James river, in front of the canal. Our return fire was so heavy that they fell into the error of concealing these batteries behind clumps of trees, and thus lost, what is really essential to success, a good view of the target from the battery itself. The result was that their range was faulty, and their shells fell chiefly from forty to one hundred yards to the eastward of the canal, where they literally ploughed up the ground. This error enabled our working parties to continue the excavation with comparatively little loss, but suffering greatly from the harassing nature of the fire.

"A second error, worse than the first, committed by the Confederates at Dutch Gap was in not sufficiently multiplying their fire. They never used more than four or five mortars, and these chiefly Coehorns. Not less than twenty, and these eight and ten inches in calibre, were required. I am confident that this number could have been placed in position in such a man-

ner that no efforts on our part could have compelled their silence; and that well served, they would have effectually prevented the digging of the canal.

"To check their fire as much as possible, 10-inch, 8-inch, and Coehorn mortars were used—advantage being taken of the high signal tower at Crow Nest to correct errors of direction—and also horizontal fire of shell and case shot from field guns, and, occasionally, from a 100-pounder rifle, to annoy the Confederate gunners in watching the effect of their shot. To compel, by such means, resolute soldiers like these Confederate artillerymen, to suspend fire from well-constructed mortar batteries was impossible; but the precision of their practice was so much impaired that the work on the canal could continue."

After this interesting introduction, General Abbot goes on with that careful attention to details so characteristic of him to give an exhaustive account of the construction, transportation, emplacement, ammunition, service, effectiveness, and possible improvements of mortars, smooth-bore and rifled guns, and the use of entrenchments. This account embodies the results of field service and experimentation extending over a period of several years of warfare. Naturally the progress of the science of artillery renders much of this treatise obsolete, but as indicating his constant passion for accurate research it takes a worthy place among General Abbot's writings.

Another subject which the war brought prominently forward greatly interested him, and became General Abbot's major field of research during many years after. It is the subject of submarine mining. He gave a most interesting account of it in a paper read January 10, 1880, before the Military Service Institution, and published in pages 203 to 224 of Volume I of its Journal. After referring to early suggestions, little followed up either in this country or in Europe, he traces the very considerable development, especially on the part of the Confederates, of this arm during the Civil War. Very interesting is a table which he compiled from official sources showing how disastrous submarine mines proved to the shipping, particularly of the Union forces:

STEAMERS DESTROYED OR CRIPPLED BY TORPEDOES, DURING THE CIVIL WAR

Date	Vessels					Injured		
	Name	Service	Class	Tons	No. of guns	Where	Extent	Torpedo
Dec. 12, 1862	Cairo	U. S. Navy	Armored	512	13	Yazoo River	Destroyed	Mine
Feb. 28, 1863	Montauk	"	Monitor	844	2	Ogeechee River	Seriously	"
July 22, "	Baron De Kalb	"	Armored	512	13	Yazoo River	Destroyed	"
Aug. 8, "	Com. Barney	"	Gunboat	513	4	James River	Disabled	"
Sept. —, "	John Farron	U. S. Army	Transport	. . .	. .	"	Seriously	"
Oct. 5, "	Ironsides	U. S. Navy	Armored	3,486	18	Off Charleston	"	Spar
Unknown	Marion*	Confederate	Unarmored	. . .	. .	"	Destroyed	Mine
"	Ettiwau	"	"	. .	. .	"	Seriously	"
Feb. 17, 1864	Housatonic	U. S. Navy	Sloop of war	1,240	13	"	Destroyed	Spar
Feb. 17, "	Fish Torp. Boat	Confederate	Torpedo boat	. . .	. .	"	"	Own
April 1, "	Maple Leaf	U. S. Army	Transport	508	. .	St. John's River	"	Mine
April 6, "	Gen. Hunter	"	"	460	. .	"	"	"
April 9, "	Minnesota	U. S. Navy	Flag ship	3,307	52	Newport News	Internally	Spar
April 15, "	Eastport	"	Armored	800	8	Red River	Sunk	Mine
May 6, "	Com. Jones	"	Gunboat	542	6	James River	Destroyed	"
May 9, "	H. A. Weed	U. S. Army	Transport	290	. .	St. John's River	"	"
June 19, "	Alice Price	"	"	320	.	"	"	"
Aug. 5, "	Tecumseh	U. S. Navy	Monitor	1,034	2	Mobile Bay	"	"
Oct. 27, "	Albemarle	Confederate	Armored	. . .	2	Plymouth	"	Spar
Nov. 27, "	Greyhound	U. S. Army	Transport	900	. .	James River	"	Coal
Dec. 8, "	Narcissus	U. S. Navy	Gunboat	101	2	Mobile Bay	"	Mine
Dec. 9, "	Otsego	"	"	974	10	Roanoke River	"	"
Dec. 9, "	Bazley	"	Tug	. . .	. .	"	"	"
Jan. 15, 1865	Patapsco	"	Monitor	844	2	Off Charleston	"	"
Feb. 20, "	Osceola	"	Gunboat	974	10	Cape Fear River	Crippled	Drifting
Unknown	Shultz†	Confederate	Transport	. . .	. .	James River	Destroyed	Mine
Mar. 1, "	Harvest Moon	U. S. Navy	Gunboat	546	3	Georgetown	"	"
Mar. 4, "	Thorne	U. S. Army	Transport	403	. .	Cape Fear River	"	"
Mar. 12, "	Althea	U. S. Navy	Gunboat	72	1	Blakely River	"	"
Mar. 28, "	Milwaukee	"	Monitor	970	4	"	"	"
Mar. 29, "	Osage	"	"	523	2	"	"	Drifting
April 1, "	Rodolph	"	Gunboat	217	6	"	"	Mine
April 13, "	Ida	"	"	104	1	"	"	"
April 14, "	Sciota	"	"	507	5	Mobile Bay	"	"
May 12, "	R. B. Hamilton	U. S. Army	Transport	400	. .	"	"	"
June 6, "	Jonquil††	U. S. Navy	Gunboat	90	2	Ashley River	Seriously	"

* Blown up accidentally when planting mines (General Beauregard).

† Flag of truce boat blown up accidentally by a Confederate mine when returning to Richmond with exchanged prisoners of war. ††Injured while raising frame torpedoes.

He remarks:

"Wholesale destruction, like that shown by this table, did not fail to attract the notice of every nation possessed of a sea-coast and a navy. How to make use of the new weapon to defend the former, and to increase the offensive powers of the latter, at once received earnest attention. The investigations thus inaugurated have been actively continued to the present day, but the results, as far as possible, are kept shrouded in mystery. Indeed it is altogether probable that until war compels a general showing of hands, not a few trump cards will never see the light."

He then lays down the fundamental law of naval operations, and supports it by quotations from the highest authorities, that the fleet is not to be used for harbor defense, but for offensive expeditions. Heavy guns in fixed forts must be the reliance for shore defense. But since the experience of the Union fleets at Mobile and New Orleans plainly showed that an energetic admiral may pass the fortifications without fatal losses, it becomes the province of submarine mines to obstruct the channel and hold the enemy's ships under the fire of the heavy guns until they work destruction upon them.

He proceeds as follows:

"The foregoing considerations sufficiently explain the reasons for the establishment of a school of sub-marine mining at Willets Point. A brief outline will now be given of some of the more important investigations which have been conducted there to develop this new branch of national defense.

"The first subjects of study were to determine the best explosive for use in sub-marine warfare; its destructive range against a first-class modern ship-of-war, built of iron upon the double cellular principle; and the effect produced upon this range by variations in the depths of water, the submergence of the charge, the material of the envelope, the air space in the torpedo, and the nature of the fuze—in a word the laws governing the effective transmission of the energy developed by the

explosion through the water to the vessel, and the minimum amount of this energy which may be regarded as certainly destructive.

"Nothing can be accomplished in such an investigation without numerous and accurate measurements.

"Major King had already shown that the Rodman gauge could be used under water; but certain difficulties which he had encountered indicated the necessity of modification in the apparatus before it could be employed with large charges. These modifications, and a new method for determining the scale which avoids the theoretical objections pointed out by Prof. Bartlett to the use of a compression machine, were successfully accomplished.

"It was inferred at the outset—and experience has abundantly confirmed the truth of the inference—that in order to secure determinate results the gauges must be held rigidly in position when acted upon by shock. Different methods were adopted.

"In the first, the charge was lashed in the center of a stout wrought iron ring (3 ft., 4 ft., 5 ft., or 6 ft., in diameter) upon which six gauges were secured in such a manner as to point directly at the charge. This apparatus was suspended in a vertical plane at any desired distance below the surface, by wire rope connected with a wrought iron buoy. By this method any particular experiment could be repeated as often as necessary under identical circumstances; and any single element could be varied without modifying the others.

"Several hundred trials have been made with this apparatus, including comparative tests of mammoth powder, cannon powder, Oliver powder, mortar powder, musket powder, fine sporting powder, safety compound of the Oriental Powder Company, compressed gun cotton, dry and wet, granulated gun cotton, nitro-glycerine, dynamite (2 grades), dualin, rend-rock (3 grades), vulcan powder (2 grades), mica powder (2 grades), hercules powder (2 grades), electric powder (2 grades), Designolle powder and Brugere or picric powder.

"This list includes characteristic types of all explosives known to modern science which are suitable for use in sub-marine mining. In connection with many other tests covering wetting, freezing, long storage and sympathetic explosions, the experiments have shown that dynamite No. 1, consisting of 75 per cent of nitro-glycerine and 25 per cent of keiselguhr, is the best for our service.

"In so extended an investigation many new points have naturally been developed, but only a few of them can be mentioned here.

"The fundamental distinction between explosive mixtures and explosive compounds is strongly marked in subaqueous explosions. The former burn gradually, and with any strength of envelope likely to be used in sub-marine mining only a small fraction of the theoretical potential energy can be utilized, even when many well distributed points of ignition are employed. The compounds, on the contrary, when detonated waste but little of their full strength. This difference renders hardly possible any direct comparison between these two classes when fired under water.

"The element of time, even with explosive compounds, has proved to be of extraordinary importance. Thus nitro-glycerine exploded under water develops but little more than 8/10 of the intensity of an equal weight of dynamite No. 1, thus suggesting the apparent paradox of a part being greater than the whole. The explanation is believed to lie in the fact that its action is too sudden to be well suited to a resistance like that opposed by water.

"The interposition of a stout wooden case between the charge and the water reduces in a surprising degree the kinetic energy available for effecting destruction upon an exterior object. Thus, with small charges of an explosive compound, a wooden case 2 inches thick absorbs from 40 to 55 per cent of the energy registered upon the gauges when a tin case is used.

"To determine the laws governing the transmission of the shock horizontally through the water to considerable distances, a light wrought iron frame 50 ft. long by 10 ft. by 10 ft. was

employed. The charge was secured at the central point, and 36 gauges, placed symmetrically with respect to a horizontal plane passing through it, were rigidly secured at the angles between the transverse frames. This 'crate,' so called, was suspended below the water surface by two buoys, and charges of dynamite varying from 5 lbs. to 100 lbs. were exploded, and the intensities of their action measured.

"A close study of many experiments with the apparatus above described has fixed the numerical values of certain constants entering a general equation framed upon well established mechanical principles; and has proved that one and the same formula can be applied to all the modern explosive compounds by substituting the proper numerical value for a single constant.

"This discovery has rendered it easy to fix the relative value of the several explosive compounds, and to compute for each the intensity of action which the explosion of a known charge at a known distance will develop in any known direction.

"The complete solution of the problem of destructive range for subaqueous explosions required, in addition, that the intensity of action needful to destroy a first-class modern ship of war should be ascertained.

"To determine this intensity, an iron target was prepared representing a section twenty feet square from the bottom of the Monarch, a vessel constructed upon the double cellular principle. This target was so moored as to secure by the use of heavy anchors and chain cables, strained by a tidal lift, much greater stability than would be given by its own weight; and a systematic series of tests was conducted in the years 1875-7. One numerical value for the intensity of action needful to effect destruction was thus deduced.

"The English official tests upon the Oberon, conducted during the years 1874-6, were reported in professional journals and the daily papers in so great detail that by the aid of the formulæ above mentioned a satisfactory discussion of them was possible, although the official conclusions reached by the royal engineers have never been publicly announced. In this manner

a second and independent value of this important element of the problem was secured.

"Certain preliminary trials conducted at Willets Point upon a very strong wooden raft afforded a third value.

"These three determinations were so accordant that we have reason to be satisfied with the value finally adopted by the board of engineers; and the size of the charges for our mines and their destructive range have been fixed accordingly."

For nearly twenty years, General Abbot, commanding the Engineer School of Application at Willets Point, or detailed to various Boards charged with seacoast fortification and harbor improvement, devoted much of his great research ability to the improvement of those combinations of high explosives and electrical mechanisms which are at the basis alike of modern engineering and of coast defense in warfare. Of the Engineer School his son, Gen. F. V. Abbot, writes:

"After the war was over he was in command of the Engineer Battalion, and under the direction of General Humphreys, then Chief of Engineers, he established in 1866 the 'Engineer School of Application' to which all Engineer graduates reported upon graduation. This 'School' was almost the opening gun in the long campaign for education of Army officers in post-graduate schools. I believe that the only Army School antedating the Engineer School of Application was the Artillery School at Fort Monroe. The Engineer School did not receive official recognition by the Adjutant General in those early days because 'It was not under the Adjutant General, but only under the Chief of Engineers, and so was not properly an Army School.' Those of us who took the courses in those same early days know from the way we had to work to keep up with the requirements that it was a most real school so far as its students were concerned. From the start it was practical as well as theoretical but included much military history and art of war. My father always held that Engineers were *primarily* soldiers, but in addition had to acquire much scientific knowledge. Astronomy as applied in boundary surveys, then often

assigned to the Corps of Engineers, and practical application of the natural sciences formed part of the curriculum.

"At the very start when buildings, books, etc., were hard to get for the school it was my father's custom to assign to lieutenants some French book on a military subject for translation. To one officer, later a most effective Chief of Engineers, was assigned thus, 'Defenses des Etats,' a book of several hundred pages. The young officer thought to himself, as he has often told me in later years, 'The General evidently has forgotten the French he learned at West Point and wants my help to learn what this infernally big book contains,' and went at his job with enthusiasm, and spent many an hour transcribing his translation with unusual care, as his penmanship, like many another's was not all that could be desired. At this date all officers of the Battalion and School were quartered in the one-story cantonment buildings built for the Medical Department for hospitals during the Civil War. They were not sheathed or plastered and were 'warmed' ??? by old fashioned cast iron stoves. Warmed is a relative term, and often the translator's ink froze in the evenings though not more than a few feet from one of these 'Heaters.' One especially cold night one of his classmates and a mutual friend climbed to the roof and dropped a large snowball down the sheet iron stove pipe, which was all the chimneys had on any of the quarters, from the Commanding Officer's, to the smallest barracks. When the snowball reached the hot coals there was an explosion which blew the stove door open, and a rush of steam, smoke, and soot utterly ruined the 100 pages of manuscript of the 'Defenses des Etats.' The next morning the Lieutenant reported at the Adjutant's Office, and apologized to my father for the long delay a recopying of the translation would involve, and expressing the hope that the Commanding Officer was not in urgent need of the same. He was disgusted when my father replied 'Why, of course I have read the book myself, and selected you to translate it only for your own good.'

. . . .

"On May 5th, 1869, my father was detailed as a member of

the New York board of Engineers on Fortifications, in those days charged with the preparation of detailed plans of defense of our sea coast against foreign naval attack. He remained a member of this board till he retired for age. For years he was its President. With the approval of the Chief of Engineers, 'Major Henry L. Abbot' was detailed by this board 'To devise and test a sub-marine system for the United States, and to train Engineer troops in its operation.' This was in 1871. In carrying out this program my father personally handled and tested chemically all then known high explosives in order to select that best adapted to use in sub-marine mines. In the course of his experiments he photographically recorded the blowing up of the schooner *Olive Branch,* a triumph in those early days when dry plates were unknown, and wet plates of sufficient sensitiveness to record with very short exposures were just in the testing stage. Thus in two dissimilar branches of chemistry my father was early at the front.

"He developed the spherical welded mine case still universally used. He actually devised and practically tested an electrically controlled system of sub-marine mining, at a time long antedating the use of incandescent lamps, and large dynamo machines. To determine the distances between sub-marine mines needed to permit the explosion of one without destroying its neighbors, he undertook the investigation of the laws of translation of destructive shocks of explosions under water, and derived a formula which indicates with extreme accuracy the pressures to be anticipated at any distance under water from the explosion of a known charge of any explosive, when once the latter's coefficients have been determined by actual explosions of small charges, where the resultant pressures can be accurately measured by proper pressure gauges.

. . . .

"He was a pioneer in the study of simultaneous ignitions of large numbers of fuzes, designing and making the electrical connections used at the Flood Rock explosion October 10th, 1885. Now with powerful high-potential dynamos such a problem would be easy, but then wet batteries were the only source

of current. With thousands of fuzes to explode, and hundreds of thousands of pounds of high explosives to be ignited under water, the problem was one of no light responsibility, but the result was a perfect success."

General Abbot's loyalty and pride towards the Corps of Engineers of which he was an ornament found expression in a historical paper, pages 413 to 427 of Volume XV of the Journal of the Military Service Institution. Having traced the formation and history of the Corps from the Revolution until 1861, he says of its service in the Civil War:

"These engineer companies after the return from Fort Pickens served throughout the Civil War with the Army of the Potomac. Space is lacking to detail their important and gallant services. The battalion was attached to the headquarters of the army, under orders of the chief engineer, and besides its special duties was often placed in line of battle. Its officers were habitually detached, as needed to serve temporarily on the staffs of generals commanding army corps and divisions. Its colors were officially authorized to bear the names of the following engagements: Vera Cruz, Mexico, 9 and 28 March, 1847; Cerro Gordo, 17 and 18 April, 1847; Contreras and Churubusco, 19 and 20 August, 1847; Molino del Rey, 8 September, 1847; Chapultepec and City of Mexico, 13 and 14 September, 1847; Yorktown, Va., 4 May, 1862; Fair Oaks, 31 May, 1862; Mechanicsville, 26 June, 1862; Gaines's Mill, 27 June, 1862; White Oak Swamp, 28 June, 1862; Malvern Hill, 1 July, 1862; Antietam, Md., 17 September, 1862; Fredericksburg, Va., 13 December, 1862; Chancellorsville, 4 May, 1863; Franklin Crossing, 5 June, 1863; Kelly's Ford and Rappahannock Station, 7 November, 1863; Wilderness, 5 and 6 May, 1864; Po River, 8 May, 1864; North Anna, 23 May, 1864; Cool Arbor, 3 June, 1864; Siege of Petersburg, June, 1864, to April, 1865.

"Immediately after the close of the war the headquarters of the battalion were established at Willets Point, New York harbor, where has been gradually developed the present Engineer School of Application. . . .

"*War Record of the Corps of Engineers*—Beside the military duties assigned to engineer troops, there are important professional functions which devolve upon engineer officers serving on the staff of generals commanding armies in the field; and in our service the command of volunteer troops, as well, has often devolved on officers of the Corps. In every war with a civilized power since the earliest history of our country these duties have been performed by them in a manner to merit and receive distinguished commendation; and in all these wars their blood has been shed on the field of honor. That this is no exaggeration is shown by the following list of officers who have been killed or mortally wounded in battle since the organization of the present Corps in 1802. All were graduates of the Military Academy:

"Capt. and Bvt. Lieut.-Col. E. D. Wood, Sept. 17, 1814, Sortie from Fort Erie, U. C.

"Capt. W. G. Williams, Sept. 21, 1846, Monterey, Mexico.

"1st Lieut. and Bvt. Captain W. H. Warner, Sept. 26, 1849, by Indians near Pitt River, Cal.

"Captain J. W. Gunnison, Oct. 26, 1853, by Indians near Sevier Lake, Utah.

"Maj.-Gen. I. I. Stevens, U. S. V., Sept. 1, 1862, Chantilly, Va.

"Brig. Gen. J. K. F. Mansfield, U. S. A., Sept. 18, 1862, Antietam, Md.

"1st Lieut. and Bvt. Col. J. L. K. Smith, Oct. 12, 1862, Corinth, Miss.

"1st Lieut. and Bvt. Major O. G. Wagner, April 21, 1863, Siege of Yorktown, Va.

"Major and Bvt. Major-Gen. A. W. Whipple, May 7, 1863; Chancellorsville, Va.

"Captain and Bvt. Col. C. E. Cross, June 5, 1863, Franklin's Crossing of Rappahannock River, Va.

"1st Lieut. and Bvt. Col. P. H. O'Rorke, July 2, 1863, Gettysburg, Pa.

"Captain and Bvt. Col. H. S. Putnam, July 18, 1863, Assault of Fort Wagner, S. C.

"Captain and Bvt. Col. A. H. Dutton, June 5, 1864, Bermuda Hundred, Va.

"Major and Bvt. Brig.-Gen. J. St. C. Morton, June 17, 1864, Petersburg, Va.

"Brig.-Gen. J. B. McPherson, U. S. A., July 22, 1864, Atlanta, Ga.

"1st Lieut. and Bvt. Maj. J. R. Meigs, Oct. 3, 1864, Harrisonburg, Va.

"1st Lieut. Jacob E. Blake, Topographical Engineers, deserves to be mentioned in this list, although his death resulted from the accidental discharge of his own pistol on the field of Palo Alto after an act of the most conspicuous gallantry performed in the sight of both armies.

"Very many of the officers of the Corps have been wounded in battle, some several times, but the list is too long for the space allotted to this paper.

"During the war with Mexico 19 officers of the Corps of Engineers and 24 officers of the Corps of Topographical Engineers served actively in the field. One of them, Captain Williams, was killed, and sixteen wounds were divided among the others. Among those of this little band who subsequently, in the Civil War, reached high rank and distinction may be mentioned in order of seniority in their respective corps: Generals Mansfield, Robert E. Lee, Barnard, Beauregard, Isaac I. Stevens, Halleck, Tower, G. W. Smith, McClellan, Foster, Joseph E. Johnston, Emory, Fremont, Meade, Pope, Franklin, and T. J. Wood.

"During the Civil War the officers of both Corps with few exceptions served with the armies in the field. . . .

"It is a matter of record that 33 officers who either held or had held commissions in the Corps of Engineers, were appointed during this war general officers in command of troops. Of these, 3 became major-generals, and 3 brigadier-generals in the regular army; 15 were major-generals, and 12 were brigadier-generals of volunteers; 8 of the 33 commanded armies; and 10, army corps. At least 8 general officers in the Confederate armies had been officers of our Corps of Engineers,

and among them were General Robert E. Lee and General Joseph E. Johnston."

Of the peace record of the Corps of Engineers he quotes from his friend General Humphreys as follows:

" 'From the earliest period, the several organizations of engineers which we have had in our service, have invariably and exclusively made the surveys for, and the plans of, our seacoast defenses, whether of a temporary character which were built up to 1818, or of the permanent character which have been since that time projected, and have superintended their construction and the disbursement of the funds appropriated by Congress for the same.

" 'Up to about 1831, its officers were to a great degree the repositors in this country of that knowledge which was requisite for the purpose of making accurate surveys. The location and construction of the roads, canals, and bridges built for the development of the resources of the country, and the accurate methods of surveying, geodetic, topographic, and hydrographic, now in use, are in a great measure due to the talents and labors of its officers.

" 'Almost all the great routes of internal communication in the interests of commerce and speedy transit, now in existence in the country, were first explored, located, and projected by officers of this Corps. The files of the bureau of the Corps in Washington, and the Congressional documents, are rich in reports upon the works of this character, that have been examined into under authority of law, by the Corps of Engineers.

" 'In the matter of the improvement of rivers and harbors, in the interest of commerce, the Corps of Engineers has had almost the exclusive control, and the information on this subject contained in reports of its officers, from the early years of this century to the present time, now filed in the Bureau of the Corps, is a monument to its labors and a most valuable collection of precedents to be used in the future prosecution of such works.

" 'The surveys, examinations, and constructions which have been made by officers of the Corps, have not been confined to

such matters as are solely in charge of the War Department. From time to time the State Department, the Navy Department, the Treasury Department, and the Interior Department have employed its officers in the running of boundary lines, and the surveys for the maps necessary to be used in delicate diplomatic negotiations; in the surveys for, and the constructions of, dock-yards; the surveys for canal routes across the Isthmus of Panama; upon astronomical observations in the interest of science; in the surveys of the coasts, the planning and construction of light-houses and other fixed aids to navigation; the planning and construction of public buildings, of custom houses, post-offices, marine hospitals, etc.; and especially in the construction of the Capitol, the General Post Office, and the Washington Aqueduct in this city.

" 'Scarcely a branch of engineering, whether military or civil, can be mentioned, that has not been improved and expanded by the study and labors of the officers of this Corps.' "

In this Corps, General Abbot served from 1854 to his retirement for age in 1895. He arrived at the top, not only in the excellence of his service but in actual seniority. Yet neither he nor his son, General F. V. Abbot, who also became senior officer of the Corps after distinguished service, and who was for many months Acting Chief, received the actual appointment as Chief of Engineers.

Chapter 5

Family Life and Occasional Occupations

General Abbot married April 2, 1856, Mary Susan Everett of Cambridge, Massachusetts, who died March 13, 1871, aged 39 years. They had four children, two sons and two daughters. The elder son, Frederic Vaughan Abbot, born March 4, 1858, graduated No. 1 in the class of 1879 at West Point, rose to be Colonel and Brevet Brigadier General of Engineers, was retired for physical disability while Acting Chief of Engineers at the age of 62 years, and died September 26, 1928. He left a widow, two unmarried daughters, and a married son engaged in civil engineering. The younger son of General H. L. Abbot, born March, 1871, died as the result of accident while spend-

ing the summer at the ancestral home in Wilton, New Hampshire, aged 10 years. The two daughters at this writing still survive, unmarried.

General Abbot was very gentle and loving in his home life, though so deeply immersed in his unremitting researches and military duties as to be rather difficultly drawn into social intercourse. Not a talkative man, he was a good listener, with face alight with kindly interest, when actually drawn out of his computations, and brought into the social circle. He received the reverence and warm affection due to an unblemished, kindly, generous character.

He was not a voluminous correspondent, nor did he, like some famous characters, make his letters very markedly the expression of his life. His daughter writes: "It was not so much in his letters themselves as in the regularity with which they came that my father showed his constant loving thought of us. Any one not with him knew that each Sunday morning he would be clicking away at his typewriter, and could count on hearing from him."

During his visit of inspection with the National Academy Commission to the Panama Canal in the year 1915, his letters home form a diary of the expedition from which I quote some passages, not so much for their historical value as to give a little closer view of the man himself, outside his official life.

"Havana, Cuba, Dec. 15, 1915. . . . All goes well except today. One of our members knows President Menocal of Cuba, who extended us an introduction to a formal reception at 9:15 a. m., later postponed to 11 a. m. We should have gone together, but no arrangement was made and we went separately. There are several secretaries at the Palace, and I and one other got into the hands of a wrong one. Receiving no notice of the reception I wasted half an hour and then left, leaving my card for President Menocal. . . . The day is lovely and I have had no occasion to change to summer clothing.

"Dec. 16. . . . We actually got off in the middle of the night. Early in a. m. could see mountains skirting the west end of Cuba. Very fine and sea smooth.

"Friday, Dec. 17. . . . More wind today, and enough rolling to make some of us seasick, but not me. We had a Commission meeting today on the slides. . . . We had a wireless telegram today from Washington 'President Wilson is 59 years old and his bride is 43.'

"Sunday, Dec. 19. . . . Nearing our port. . . . Letters mailed on board ship are at arrival transferred to next ship to sail north. . . . So this little sheet will first go north and then the long trip across the Continent before you get it. Let me know when it arrives so I can count the days it is on the road. Shall be too busy to write much, and it would be no use to mail one when I *start*. So do not worry if a long interval occurs. We rather expect to leave on Jan. 2 but may not do so. Love and kisses from

"PAPA."

"Jan. 3, 1916. . . . Here we are homeward bound. . . . The sea today is smooth but several are sick, but I *am all right*. . . . It has been a pleasant trip, and the changes have been so great on the Isthmus that it seems a new world to me.

"Jan. 4. . . . Slight rolling sea. I am all right, and have plenty of room at table for *many* are not. The birthday of my little war daughter is approaching, and as she may find funds useful in her wanderings, I shall endorse the check to her instead of her 'agent.'

"Jan. 7. . . . We lay fog bound at anchor off the entrance of the Mississippi Pass until 7 a. m., when we entered and are slowly creeping up the river, the fog too dense to see the details of the jetty works. We hope to reach New Orleans in time to catch the 9:35 p. m. train for New York. My plan is . . . to proceed to Cambridge to await your arrival. If that occurs in May, I shall have to go to Dartmouth meeting and perhaps to the meeting of the National Academy of Sciences in Washington in April. So the date when we meet again is a long distance in the future. . . . I am feeling finely, having had no illness since I started on this long trip.

"Love and kisses from

"PAPA."

"Jan. 9. . . . Just arrived [in New York] after the long journey from the Isthmus. Find all well here. We had a nice trip and I hope the worst is over with the slides. Ships drawing not over 21 feet were passing when I left. The difficulty is now limited to about a mile in distance, and the fight will end there probably for the future. . . .

"H. L. A."

"Cambridge, February 20, 1916.

"DEAR MAY:

"So May cannot get before May, but she may get behind May. What kind of a dress does May have on to be such an obstruction?

"We are having a remarkable kind of winter. Day before yesterday the mercury read at breakfast, dinner and supper 34°, 42° and 39°. Yesterday these figures were 15°, 15° and 11°. Today it begins at 10°. The lowest I have read was 2°. The snow has been a maximum for 24 years so the Transcript says. I am glad you are out of it. . . . During the warm days one has to swim to get over the streets, and during the cold days look out not to fall on the slippery ice under the snow. . . .

"Go on picking oranges, and having a nice time and come back as good as new; and you will do much to please your loving

"PAPA."

Throughout his life, General Abbot wrote much. The following list of papers was prepared by him, and shows at once the great variety of his interests, and also the concentration of his attention on subjects relating to hydraulics; to indirect artillery fire; to submarine mining, and the use of high explosives; and through a very long period to the subject of the Panama Canal.

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Among many interesting observations done under his direction, there was a series of latitude observations at Willets Point designed primarily as practise in the use of astronomical instruments by the young engineers. But so exacting was the accuracy demanded, and so painstaking the record, that a ten-year series indicated clearly that wandering of the earth's pole which was investigated by Chandler about ten years later, and afterwards continuously observed by international cooperation.

General Abbot also continued for many years to record at Willets Point the aurora borealis. His long (unpublished) series of observations brings out very clearly the association between terrestrial auroræ and the sunspot numbers.

At the time of the improvement of the approaches to New York by the blasting of the Hell Gate ledges, General Abbot arranged an elaborate system of observations for determining the rate of propagation of the earth waves. His report thereon in pages 691 to 704 of the Annual Report of the Chief of Engineers, Part 1, 1886, is full of interest. The following table of results, whose divergences the context leaves no room to attribute to careless observing, is most extraordinary.

DATA AT THE FLOOD ROCK EXPLOSION

Stations	Distance from Flood Rock	Magnifying power of telescopes	Earth wave			Velocity of transmission in miles per second	Remarks
			Arrived in	Mercury in agitation	Earth tremor lasted		
EASTERLY COURSE THROUGH DRIFT							
	Miles		Sec.	Sec.	Sec.		
Willets Point	8.33	14	8.5	80	..	0.98	By mercury
			8.8	..	62	...	By galvanometer
Pearsalls	16.78	14	6.6	104	86	2 54	
Bay Shore	36.65	18	13.0	35 (?)	..	2 82	
Patchogue	48.52	19	15.4	54	36	3 15	
Goat Island	144.89	15±	58.8	74	56	2 46	
Harvard Observatory	182.68	750	219.8	95+	..	0.83	
NORTHERLY COURSE THROUGH ROCK							
West Point	42.34	31	13.6	76	58	3.11	Lieutenant Mott
		16	10.9	70	52	3.88	Lieutenant Beach
		36	10 9	92	..	3.88	Lieutenant Stuart
Litchfield Observatory	174.37	25	45.0	49+	..	3.88	Professor Peters
		45	45.2	..	..	3.86	Mr. Borst

General Abbot remarks:

"These observations indicate: (1) an extraordinary velocity of wave translation in both directions—which confirms my deduction from the Hallet's Point and certain torpedo explosions, that 'the more violent the initial shock the higher is the velocity of transmission.' At Flood Rock the charge was about six times as large as at Hallet's Point, and the velocity was from two to three times as great, over essentially the same route. (2) The uniformity of velocity to the northward, where the strata consists largely of homogeneous gneiss rock, and where the velocity even for 175 miles exceeded 20,000 feet per second. (3) The varying velocity which appeared to characterize the wave moving to the eastward, through the drift formation of Long Island. Here there seems to have been a gradual increase of velocity, followed by a decrease as the wave advanced—but on the whole a decidedly less rapid rate is indicated than in traversing solid rock, as might be expected in media of varying density and elasticity. The result, although not inconsistent with the Hallet's Point observations, was not discovered from them, except as to the decrease in velocity as the wave disappeared. This is the only point where the four deductions from the earlier observations are modified by this later and more accurately observed explosion.

"The very slow rate of movement to Willets Point is so surprising that it has received the closest scrutiny, but the evidence seems to establish its correctness. The latter rests (1) upon the determination of the absolute instant of explosion; and (2) upon the observed arrival of the tremor, closely verified by the galvanometer observations. The resulting velocity is also roughly confirmed by the observations at Astoria, as will be explained in discussing the photographs.

"The Flood Rock explosion appears to have caused a continuous earth tremor, which, observed under a magnifying power of about 18, lasted about one minute throughout the whole region covered by the observations, the maximum disturbance leading the advance, or nearly so, for at least 50 miles. At extreme ranges the tremor appears to have broken up into

successive waves, with well-marked intervals between them. These facts, the instantaneous nature of the explosion shown by the photographs, and the varying rates of advance through strata not homogeneous, appear to warrant the conclusion that the oscillation followed different routes to any given point—some near the surface, and others at greater depths, where more dense and elastic strata produced changes in the direction of the wave front and yielded higher velocities.

"The whole subject is evidently too complex to warrant definite conclusions as to the velocity of ordinary earthquake waves, where the intensity of the original disturbance must always remain unknown."

He was appointed on two important commissions for the National Academy of Sciences. The first appointment at the request of the Secretary of the Interior, was to the Forestry Commission of the years 1896 and 1897, which was so influential in the organization of the present national forest service. Though then 66 years of age, "he was equal to anyone of the Commission in riding the difficult and in places dangerous trails."

Again in 1915 the President requested the Academy to investigate the Culebra slides at the Panama Canal. Though 84 years old, General Abbot accepted appointment on the Committee of the Academy, refused to let his son or any other near friend accompany him, and visited the Isthmus with the Committee. One of the other members remarked afterwards, "General Abbot was one of the most mentally and physically active of all of us, and went everywhere, in spite of the heat, steepness of the climbing, and in many places uncertain and dangerous trails over the material which had moved, and which was liable to start again at any time."

From May, 1905, to June, 1910, General Abbot was Professor of Hydraulic Engineering on the faculty of graduate studies of George Washington University, and for 23 years he was an active member of the Board of Overseers of the Thayer School of Engineering at Dartmouth College, resigning at the age of 87 years.

Chapter 6

General Abbot and the Panama Canal

One who has read the numerous papers of General Abbot, in which appear the extensive investigation, the keen analysis, the tireless advocacy which he devoted to the lock canal across the Isthmus of Panama, and who is informed of the many occasions when the project came within an ace of abandonment, but was saved by the General's forceful testimony, can appreciate to some degree, at least, the glow of exultation with which he must have looked in 1915, at the age of 84 years, on the triumphant success of this world-famous piece of engineering which owed so much to his exertions.

Retiring for age in 1895 from the Corps of Engineers of which he had been so great an ornament, General Abbot was employed for a time as consulting engineer by the Wisconsin Central Railroad to prepare plans for the development of the harbor of Manitowoc, Wisconsin. In 1895-6, he was also president of a board of consulting engineers on a project to connect Lake Erie with the Ohio River by a ship canal. This project did not come to fruition, doubtless owing to the railroad influence.

On his return from the expeditions of the Forestry Commission of 1896-7, he received a telegram from Mr. Maurice Hutin asking a meeting in New York. This resulted in an offer from the Chief Engineer of "La Compagnie Nouvelle du Canal de Panama" of a place on the *Comité technique*. At first loathe to be connected with an enterprise at that time so besmirched by the circumstances of the fiasco of the de Lesseps enterprise, the frank attitude of the management of the New Company won his serious attention, and at length his cordial cooperation.

Under a concession from the United States of Colombia, dated March 20, 1878, M. de Lesseps, the famed promoter of the Suez Canal, had organized the Interoceanic Canal Company, which from 1881 to 1888 carried on operations designed to construct a sea-level canal across the Isthmus of Panama. The work was practically discontinued in 1888 under distress-

ing financial conditions, and the affairs of the company passed into the hands of a receiver. He constituted a commission of French engineers, which after examination of affairs on the Isthmus, reported that it seemed feasible to complete the project as a canal with locks, but that the data available were "far from possessing the precision essential to a definitive project."

The receiver, following this hint, organized with considerable difficulty the New Panama Canal Company under an agreement safeguarding the interests of the stock and bond holders and creditors of the old company. The New Company was bound to raise 65,000,000 francs, to study with the aid of experts the problem of the Canal, and after the expenditure of half its capital to unite with the representatives of the old company to select a commission to make a definite report on the course to be adopted.

The New Company, therefore, appointed a technical committee of eminent engineers representing the countries of France, Holland, Germany, Russia, England, United States, and Colombia, on which committee General Abbot, as stated above, accepted membership. Under the direction of this committee a great amount of investigation and excavation was done at the Isthmus, so as to determine fully every question raised by the deliberations relating to the best type of canal. These questions had to do with the geology of the Isthmus, the survey of its watersheds, the gauging of its rivers, the cost of excavation in all strata to be encountered, the safety of dam foundations, the questions of meteorology and related flood conditions, the probable tonnage and character of the ships likely to be accommodated, in a word everything which governed the cost, time of construction, usefulness and safety of a canal across the Isthmus of Panama.

In these investigations General Abbot took such a leading part that, as we shall see, he was nominated by the Directors of the New Company to be one of its two representatives on the commission which was to make the final definite recommendation of the plan to be pursued. The significance of this action by French Directors of a French project is apparent.

The *Comité technique* reported unanimously on November 16, 1898, proposing a definite project estimated to cost about $100,000,000, to be completed in about ten years, and suited to meet amply the needs of commerce for a long time to come. Thereupon the Commission of five members arranged for by the agreement was nominated, and of this Commission General Abbot had the distinction of being the only foreign member. After a thorough inspection of the work on the Isthmus, of the results of the investigations made, and of the records of all kinds, the Commission rendered its report on February 28, 1899, containing the following unanimous conclusions:

"In fine, the investigations for the completion of the canal have been conducted in a practical and scientific manner, and upon the most judicious methods.

"The basis on which the project rests has been established by actual experience, and by precise observations upon existing conditions, which the old company began and which the New Company has completed and rectified with the greatest care. The precision of this basis is then certain.

"The three solutions presented meet equally the needs of commerce and are feasible, from a technical point of view, under the conditions of time and expense contemplated, and with the means of execution heretofore in use on the Isthmus. There are, however, good reasons to believe that these means can be sensibly improved when the time comes to begin work, by resorting to improved apparatus and by better dispositions for operating upon a large scale.

"Consequently the Commission is of the opinion that the adopted project is practicable under the conditions of time and expense indicated, and that the New Company has demonstrated that by works which will not exceed an outlay of about one hundred million dollars, and a duration of about ten years it is possible to open the Panama Canal to extensive commerce, to remove the obstacles which the Isthmus opposes to international communication, and thus to complete an immense work that interests all the nations of the world and is the greatest which human genius has ever planned."

The New Company was, of course, fully aware that the Maritime Canal Company, an American concern, was seeking to promote the project of a canal through the country of Nicaragua. Being absolutely sure of the great superiority of the project at the Isthmus of Panama, both as regards engineering feasibility and convenience of operation, no attention was being paid to this rival project, when our War with Spain and the adventure of the battleship *Oregon*, which made the complete circuit of South America to operate in the West Indies, changed the situation completely. An imperative demand arose in America for an interoceanic canal to be owned and controlled by the Government of the United States. Congress was almost definitely committed to the Nicaragua route.

The directors of the New Company realized that the unlimited means of the United States Government made the Nicaragua Canal a certainty, and the difficulty of getting funds to construct a rival canal at Panama almost insuperable. Also the problem of securing labor to work on two great tropical engineering operations would be exceedingly difficult. Accordingly the Directors transmitted the report of the *Comité technique* to President McKinley, in order that the Government might be thoroughly informed of the very different aspect of the Panama project since the completion of the elaborate investigations described.

At the hearing before the Committee on Interstate and Foreign Commerce of the House of Representatives, beginning January 17, 1899, General Abbot was put forward as the principal technical witness of the New Panama Canal Company, and testified in part as follows:

"General Abbot: Perhaps it is proper for me, being an American, to explain my position to the committee. I graduated at West Point and served forty-one years in the Corps of Engineers, United States Army, passing through all the grades up to colonel, inclusive, and being retired for age in 1895.

"During the last seven years of my service I was president of the permanent Board of Engineers in New York, to which are referred the more important questions which come under

the attention of the Chief of Engineers. I was also division engineer for the general supervision of all the engineer constructions in the northeast division, which includes all of New England, New York, New Jersey, Delaware, the Delaware River at and below Philadelphia, and Lake Erie as far west as Toledo. Since then I have been in the active prosecution of the profession of civil engineering. Without any application on my part I have prepared the plans for the new harbor at Manitowoc. I served as the president of the board of consulting engineers, which was established under the Chamber of Commerce of Pittsburgh, in reference to the new ship canal projected from Pittsburgh to Lake Erie.

"I received an invitation from the New Panama Company to join their technical commission, and I will be frank to say that at first I hesitated about accepting it, because I had the general American prejudice that the canal was dead, and I did not care to associate myself with something that was not likely to be successful. But I was assured by Mr. Hutin, the director-general of the New Company, that if any person in the world wanted to know the fact if the completion of the canal was impracticable it was the company itself, because the question with them was one of investing their money, and if I was right in supposing the canal impracticable they wanted to know it.

"With that understanding I went to Paris in May, 1897—nearly two years ago—and last spring I spent three weeks on the Isthmus, going through the route thoroughly, including the Haut Chagres, on horseback and in boats, and looking at everything that is to be done. I have been serving on the technical commission at Paris the rest of the time.

. . . .

"A definite and final conclusion has been reached as to the project for the canal. The recent work of excavation done on the Isthmus has been directed to fulfill two objects. One has been to remove many cubic meters out of the most difficult cut, doing that much toward the completion of the canal. The other has been to do it in such a way as to throw light upon

the future operations, including side slopes, unit cost, etc.; that is, instead of working on the whole width of the canal, as the old company was doing, the New Company has sunk a deep cunette, only 30 feet wide at the bottom, to explore in that direction and secure information as to what will be encountered hereafter. . . .

"I may now say a word in general terms about the project before going into details. The great ship canals of the world are limited in number. The Manchester Canal is the only one in which interior locks are required. The Kiel Canal requires locks at its entrances simply to regulate the tide, of which there is a large one on the North Sea and a small one on the Baltic. I have been through both and studied them both. Comparing the existing canals—the Suez, the Manchester, the Kiel canals, and the other great canals of the world—the adopted project for Panama is second to none. In some respects it is the best. The locks are larger than in any other. They could pass the *Oceanic,* the largest ship in the world.

. . . .

"There are two great engineering problems connected with this canal. The first one is the regulation of the river Chagres. That river comes down from the mountains shown here on the map [indicating on map], and strikes the line of the canal at Gamboa. It then flows through a hilly country, but here at Bohio it leaves the line of the hills to traverse a low district to the Atlantic. Indeed, the river at its low stage reaches the level of the sea at this point—Bohio. The Chagres is a torrential stream. It was a matter of great importance to note what the floods were, what volume they carried, and what means were necessary to control them. On my arrival at Paris I was surprised at the extent of information which the company had collected in that matter. I had served for four years with General Humphreys on the Mississippi River, and was somewhat familiar with such investigations, and I must say that the work was admirable.

"We have here at Gamboa a continuous record of the height of the water, printed automatically on a tide gauge or, rather,

fluviograph, that record extending from 1880 to the present time. So the New Company has had its finger on the pulse of the river for nineteen years. There were discharge measurements made at the same place for a period of seven years, averaging about nine days during the month, and, if any special floods came down, a larger number. For six years similar measurements were made at Bohio, and for two years at Alhajuela. In order to be sure of a correct relative determination, daily measurements were taken at these three stations for thirteen consecutive months. I have studied the original reports received, giving the velocities and the areas and all the details and I may say now that we know the Chagres River as well as any river in the United States.

. . . .

"Mr. Bennett: What is the deepest cut?

"General Abbot: The original cut at the divide, when the company first began, was above sea level 344 feet. The present level of the bottom of the cunette is about 176 feet, giving an excavation of about 168 feet. Nearly down to that level it is actually excavated. With our project, the official project, the intermediate project, the bottom of the canal will be 68 feet high, which will mean 108 feet more to be excavated to reach to 68 feet above the level of the sea. All these levels mean above the level of the sea.

"Mr. Mann: How much of a cut will that make?

"General Abbot: About 276 feet, or something like that, from the original level, but not from the present level. The present level is not estimated from the whole canal cut, but from the bottom of the cunette; from that it is only 108 feet.

"Mr. Bennett: And that will extend about 7 miles?

"General Abbot: No; that is the deepest. The summit level here [indicating on map] is divided here, as you will see on the profile [indicating on map].

"Mr. Bennett: Just generally——

"General Abbot: The deepest cut is restricted to the Culebra, which is less than a mile long. What we call the Emperador,

which is the portion extending between Culebra and the Obispo, is very much less than that.

. . . .

"That brings us down to the canal as we propose. The old company had completed altogether, with the works of the New Company, about 50,000,000 cubic yards. So we have 50,000,000 cubic yards taken out and 67,000,000 still to do. That shows that the canal is almost half done, estimated by the number of cubic yards of excavation, which gives a positive measure, more definite than to give it in average depth of cut.

"Now, in reference to these dams. The dam at Bohio, which is at the lower locks, is represented on this map at this point [indicating the map]. The line of the canal is shown by this red line. At Bohio the line of hills which forms the projected lake crosses the river at a place where the dam is projected. Its total length is 1,285 feet. Its maximum height is 75 feet. The depth of water at the dam will vary between 52 feet and 65 feet, according to the level of the lake.

"A great many borings have been made, and they show that both banks are rock. The bed of the stream is at first sand, changing to what the geologists say is a tertiary clay. It is not a deposit of the present period. It forms a good foundation.

"Mr. Hawley: An impervious clay?

"General Abbot: Yes; an impervious clay that Mr. Fteley and all the experts say is a perfectly practicable foundation for an earthen dam. It is not suited to masonry, because we never build a masonry dam unless we can get rock. This shows the cross section [indicating]. This has all been determined by borings, and we know at what depth we shall reach this stratum of clay [indicating on map]. That shows a cross section of the dam. At the foot of the upper slope is a trench cut down to the clay bed and filled in with concrete so as to make a perfectly secure protection against infiltration at the bottom [indicating]. The whole upper slope of the dam is covered with rock flagging laid in cement, so as to make a tight water cover on that side [indicating]. The lower side is covered with rock flagging laid dry, so if any water should get in it could get out

without making trouble. The actual width at the top is 15 meters, or 49 feet.

"It is easy to build this dam, because the locks are projected here in a cut through the rocky hills; and the river can be deflected through this cut by a little provisionary dam or dike here, without adding to the cost [indicating on map], while the dam is constructing. So, as a problem in dam construction, this case is entirely within the limits of ordinary engineering experience, and no serious obstacle or difficulty is presented.

. . . .

"I was speaking about the dam at Alhajuela, to create the upper reservoir. That dam, as I explained, is entirely of concrete masonry abutting on rock walls and resting on rock. It is at an ideal position for a dam.

"I have now to explain how water will be transported from the lake thus formed to the canal to supply the summit level during the three dry months of the year. This will be done by a feeder which taps the lake and is carried along the side——

"Mr. Barham: Parallel with the river?

"General Abbot: Essentially parallel; yes, sir. It follows along down on this line [indicating on map], and we have special drawings to show the details. . . .

"In passing from the Lake Alhajuela to the canal we cross the Rio Chilibre, which is a large stream, that would require a drop below the level of the feeder. Therefore, we divide the route into three divisions: First, from the lake to the Rio Chilibre, then across the Rio Chilibre, and then to the canal proper. I will speak now of the first one. This distance is about 2½ miles. It passes over a rocky ridge, which is cut somewhat by cross gullies; and to save the extra length in following around them we propose to make small masonry dikes to stop the flow, and create little ponds, which will form part of the feeder. In that way we save distance and save expense. From the dam to the Rio Chilibre we have only that kind of construction to make, with a few short tunnels under cross ridges.

"Mr. Stewart: Is that trap rock?

"General Abbot: No, sir; it is a hard, solid material which is suitable for construction. The geology of the isthmus is very complicated. We find trap veins injected through argillaceous schist and other ancient volcanic products, and more rarely calcareous rock. There is no trouble in obtaining stone suitable for concrete.

"As to this first division there is nothing especial to say, except that we make a tolerably straight route by using little tunnels under cross ridges, and little dams, or more properly dikes, to check the flow and form the little lagoons in lateral ravines.

"When we come to the Rio Chilibre we pass down to its level by the method of inverted siphons, and rise again to the general level that is necessary to carry the water to the canal itself. This use of pipes is more economical than to build the immense structure of a bridge to maintain this level. The detailed plans are all here [indicating on plan]. Starting from the Alhajuela dam at this point [indicating], we go through this rocky material with these little dikes until we come to the Rio Chilibre and its branch, the Juan Mina. The pipes are laid over the former, as shown here, and then we rise to the level of the canal again. A second inverted siphon crosses this branch of the Rio Chilibre, known as the Juan Mina. The details for these pipe lines have all been worked out. There are three separate pipes resting upon concrete and capable of carrying 25 cubic meters a second.

. . . .

"After we have passed this division we strike the third, consisting of the ordinary hills bordering the valley of the Chagres, which are traversed on nearly a straight course, as shown on this map, by means of the same system of small dykes for side ravines, forming little lagoons, and by little tunnels under cross ridges, all of which are of small dimensions. This carries us through to the point where we reach the canal itself. At the very end is a tunnel 430 meters long which carries the water into a natural valley that delivers it into the canal with moderate velocity. . . .

"To regulate the Chagres River there are two points to be considered. The first is, to check the floods enough, when they come down, to prevent any serious velocities here in the upper portion of the lake, which is narrow; and, in the second place, to prevent too much water passing Bohio to the lower level, where it might make trouble.

"To form a trustworthy estimate of these flood volumes a series of observations, extending really over nineteen years, is available, as I have already stated.

"We know since the canal work began that there have been five great floods, and that no flood occurred between 1850, when the railroad was begun, and that time which was comparable to one of those floods.

"Of those five great floods, the last one was measured accurately. That was the flood of 1893. We know definitely how much water passed in that flood. The flood of 1890 was partially measured, as were those of 1888 and 1885. The flood of 1879 was the largest within the memory of the inhabitants, and we have adopted that as our standard.

"We have water marks which enable us to estimate from our gaugings what the discharge must have been at those levels. That volume forms the basis of our estimates for regulating the flood discharge. More water flows at Bohio than at Gamboa or at Alhajuela because the rains in the lower valley contribute to increase the volume as one goes down the stream. The total volume needful to restrain the flood of 1879 at Bohio was 250,000,000 cubic meters, which is 8,800,000,000 cubic feet.

"Of this we propose to reserve 150,000,000 cubic meters in Lake Bohio and 100,000,000 cubic meters in Lake Alhajuela [indicating two different points on the map]. If a flood, even as great as that of 1879, should occur, these lakes would enable us to check its violence by stopping a large part of it in the upper lake and then holding back enough of the remainder in the lower lake to prevent damage below.

. . . .

"Mr. Stewart: Are not some of those problems connected

with the building of this canal entirely new and unknown to civil engineering experience?

"General Abbot: No, sir; there is nothing in the project which asks any engineer to go beyond the recognized rules of the profession and the regular service practice. There is nothing here which would be considered otherwise than ordinary engineering work.

. . . .

"Mr. Barham: I would like to ask if there is a project of this kind in the world, or if there ever was such a project, a project like this, carried out, creating an artificial lake, carrying water in pipes, creating another artificial lake and an artificial waterway, as planned here. Is there any parallel to this in the world?

"General Abbot: The only difference is in the size of the vessels that are to go through. On the Monongahela River, with all that immense coal commerce, the passage is regulated on this principle of locks and dams. It is a well-known method of regulating rivers.

. . . .

"The Chairman: I understand you to say that you have personally observed all portions of this projected work?

"General Abbot: I have been over it and spent three weeks on it, and looked over every foot of the ground, and have seen all that can be seen.

"The Chairman: Are you familiar with the surveys?

"General Abbot: Yes, sir; I have been through the reports very carefully. Everything was open to the members of the *Comité technique,* and I am satisfied the work has been well and carefully done.

"The Chairman: As an engineer are you satisfied as to its practicability?

"General Abbot: Entirely so. I will go further than that. I will say that there is nothing in it that has not been exceeded in difficulty elsewhere. For example, we have higher dams elsewhere. A dam is building in New York to-day 120 feet

higher than that at Alhajuela. Many earth dams are existing to-day of a larger size than this contemplated one at Bohio. The question of the Culebra is—there has been no excavation elsewhere as large as that projected—but that is a question of machinery and material. We have investigated the material and we know what that is. The machinery, of course, can be obtained; that is, any new machinery that may be needed.

. . . .

"Mr. Mann: I understood you to state that it will cost about $100,000,000 to finish the canal?

"General Abbot: Yes, sir.

"Mr. Mann: Is that based on the proposition that the cost of finishing it will be the same in proportion as the cost of the work already done?

"General Abbot: By no means; it is based on the operations of the New Company.

"Mr. Mann: I mean the work on the ground; the experience of the old company on the ground. Do you take that as a basis——

"General Abbot: Not at all.

"Mr. Mann (continuing): For future work, or do you estimate without regard to that?

"General Abbot: We base our limit prices on the work of the New Company in taking out 4,000,000 cubic yards.

"Mr. Mann: You take the estimates, then, of what the New Company has done and reject entirely the experience of the old company?

"General Abbot: We are well aware that the system of administration in the old company was not that which would be carried out in the New Company.

"Mr. Mann: I am simply asking for the facts.

"General Abbot: The cost is estimated on operations which have been conducted with care and with good engineers, and with every provision for good work.

"Mr. Mann: Then if the New Company should in fact, when it goes to work, have about the same financial administration

that the old company had, the canal would cost a good deal more than your estimate.

"General Abbot: Of course; that applies to anything——

"Mr. Mann: But I am talking about this. I am talking about facts now.

"General Abbot: Well, the New Company is organized on an entirely new basis.

"Mr. Mann: I was simply trying to get at the facts.

"General Abbot: The fact is, we assume honest administration.

. . . .

"Mr. Stewart: What do you ask of the United States? What do you expect?

"General Abbot: I simply appear as a technical engineer——

"Mr. Stewart: What do you conceive personally that the company asks from the United States?

"General Abbot: My personal wish is this—as an American, not as a representative of this company at all—I think the United States Government appreciates and the people of the country appreciate the necessity of an isthmian canal. I think before we actually begin to spend money that the whole subject ought to be investigated. Congress has appointed two commissions to investigate the Nicaraguan Canal, but since the collapse of the old company is quite ignorant of the progress and present conditions at Panama.

"Mr. Stewart: You ask no money?

"General Abbot: None.

"Mr. Stewart: You ask no franchise or corporate rights?

"General Abbot: Those questions will be answered by another person, who can answer them better than I can. You asked me my personal opinion. What I would desire would be to have an impartial hearing before a board of impartial engineers whose duty it would be to investigate the two canals and decide which would be the better. It is not worth while to construct two canals. The canal that is the better should be constructed.

"Mr. Barham: You think that that investigation ought to be made now, considering the money that has already been expended?

"General Abbot: Undoubtedly I do, because the results of that expenditure are all favorable. All it requires is a moderate sum—less than any other canal—to complete it."

It was later intimated that the New Company was authorized by the terms of the Colombian concession to reincorporate as an American company. The upshot was that an act passed authorizing the President to determine the most practicable and feasible route for an Isthmian canal, with the cost of constructing the same and placing it under the control and ownership of the United States.

President McKinley appointed the so-called Walker Commission, which after examination of both proposed routes preferred the Panama route from an engineering standpoint, but considered that the cost of acquiring the French rights was prohibitive, and recommended Nicaragua. Thereupon the President and several of the directors of the Company resigned, and after a meeting of the stockholders the Company met the figure of the Commission, $40,000,000 for all the French rights. On learning of this new condition the Walker Commission reversed its recommendation, and found the Panama route most practicable. The Hay-Herran Treaty was negotiated with Colombia to enable the United States to have full control, but the treaty was rejected in Colombia. Panama then revolted from Colombia, was recognized by the Government of the United States, and granted the desired rights over the Canal in the Hay-Bunau-Varilla Treaty which was duly ratified, and the project of a Panama Canal under the exclusive ownership and management of the United States became practicable.

The question now presented itself: What sort of a canal should it be? In this matter General Abbot's influence was the deciding factor. He had already published several articles, which were widely read, which demonstrated the enormous superiority of the Panama route. He had shown therein that

the Chagres river, long considered a very dangerous stumbling-block to the Panama canal, really lent itself admirably, with a fairly high-level lock canal, both to the convenience of construction and the subsequent operation, and that with proper construction its highest floods would be no danger or hindrance. On the other hand, he showed that the San Juan river, which formed so long a segment of the Nicaragua route, was so difficult of engineering control, and so tortuous to navigation, as to be in itself almost a reason for abandonment of the other route. Adding to this the enormous rainfall, thick fogs, frequent severe earthquakes, and treacherous harbors, prevailing in Nicaragua, there remained no question that the Panama route was highly preferable.

But now the Chief Engineer, Mr. John F. Wallace, appointed to have charge of work at Panama, preferred the so-called sea-level project (though requiring a tidal lock to control the rise and fall at the Pacific terminus). General Abbot's engineering sensibilities were outraged by this proposal, against which all the investigations of the New Company and the advice of their numerous French and foreign experts unanimously militated. Article after article issued from General Abbot's pen in popular as well as technical journals in which he marshalled that array of evidence so perfectly familiar to him, owing to his long association with the project, and proved beyond peradventure the great advantage in cost, in time of construction, in safety, and in satisfactoriness and even speed of operation of the fairly high-level lock canal over the so-called sea-level type.

His main arguments were four in number.

First: The estimated time and cost of "sea-level" canal is about double that for lock canal.

Second: In the "sea-level" canal, for 19 miles a large ship must continuously be changing her course in a channel of width only about one-quarter of her length, and at times of flood with currents as high as four feet per second.

Third: In the "sea-level" canal the highly variable Chagres river is to be arrested by an immense dam at Gamboa, rising

180 feet above the surface of the canal and only a quarter mile away. The water is to be admitted to the canal in fairly uniform manner from the lake so formed by sluices. Tributaries of the Chagres below Gamboa are to be diverted by levees and embankments. Between Gamboa and Bohio several tributaries liable to great freshets are to be controlled like the Chagres itself by large dams. Fifteen other tributaries on both banks are not provided specially for, but may pour their floods into the canal itself. In all of these complications there is so much of danger and, at best, of cross currents and streaming set up in the canal as to be highly hazardous to shipping.

Fourth: The Culebra cut, which, as later experience proved, was subject to considerable slides, would be far more formidable to the "sea-level" project because so much deeper.

Under date of April 1, 1905, President Roosevelt, dissatisfied with progress made, reorganized the Commission and provided for a new board of consulting engineers. Mr. Wallace resigned on June 25, and was succeeded by Mr. John F. Stevens as Chief Engineer. On June 24, the President appointed a board of thirteen consulting engineers of whom five were foreign experts. Among the eight American members was General Abbot, then 74 years of age.

The Board visited the Isthmus, asked for and obtained additional investigation, and developed an irreconcilable difference of opinion. Eight members, including all the foreign experts, favored a "sea-level" project with important modifications from previous ones. The other five members, of whom General Abbot was one, favored a lock canal with a summit level 85 feet above mean tide, formed by a dam at Gatun, thus substituting lake navigation over a large part of the way. Majority and minority reports, together with his own views, those of Secretary Taft, of Engineer Stevens, and of the Commission, were forwarded to Congress by President Roosevelt on February 19, 1906. These latter authorities all agreed substantially with the minority of the Board, and indeed with every commission of engineers which had previously studied the problem.

General Abbot in his book "Problems of the Panama Canal" [7] thus summarizes what happened:

"The Senate Committee on Interoceanic Canals of which Senator Millard is Chairman, acting under a resolution of the Senate adopted January 9, 1906, at once proceeded to make an exhaustive investigation of all matters relating to the Canal, the government of the Zone, and the management of the Panama Railroad Company. The printed Hearings comprise three large volumes, covering 2,967 pages, with a separate reprint (988 pages) reproducing the testimony of the engineers appearing before the Committee. Finally, on May 12, a vote on the type of canal to be recommended was taken: it resulted in a tie, five Senators favoring a sea-level and five a lock canal, each being of the general type recommended by the majority or the minority of the Board of Consulting Engineers. Subsequently, by the vote of a member absent on the first ballot, the former type was given the preference; and accordingly Senator Kittredge on May 17 reported a bill providing for the construction of a sea-level canal. On May 25 this bill was made unfinished business, and was vigorously debated for several days. In the meantime the Sundry Civil Bill containing the Canal Appropriation for the coming year was under consideration by the House, and after an able discussion of the plan to be adopted it was amended, on motion of Mr. Littauer on June 15, by inserting the words: 'Provided, That no part of the sum herein appropriated shall be used for the construction of a canal of the so-called sea-level type.' This amendment was adopted by a vote of 110 to 36. In the Senate, the bill providing for a sea-level canal was finally brought to a vote on June 21, but in a radically modified form. An amendment offered the same day by Senator Hopkins struck out all after the enacting clause and substituted: 'That a lock canal be constructed across the Isthmus of Panama connecting the waters of the Atlantic and Pacific oceans, of the general type proposed by the minority of the Board of Consulting Engineers, created by order of the President dated January 24, 1905, in pursuance of an Act entitled: "An act to provide,

[7] The Macmillan Company, New York, 1907.

for the construction of a canal connecting the waters of the Atlantic and Pacific oceans" approved June 28, 1902.' This radical amendment had been carried by a vote of 36 to 31 and the bill itself was then passed without a division. In the House this bill was passed also without division on June 27, and was signed by the President on June 29, thus becoming definitively the law determining the type of canal to be constructed by the United States."

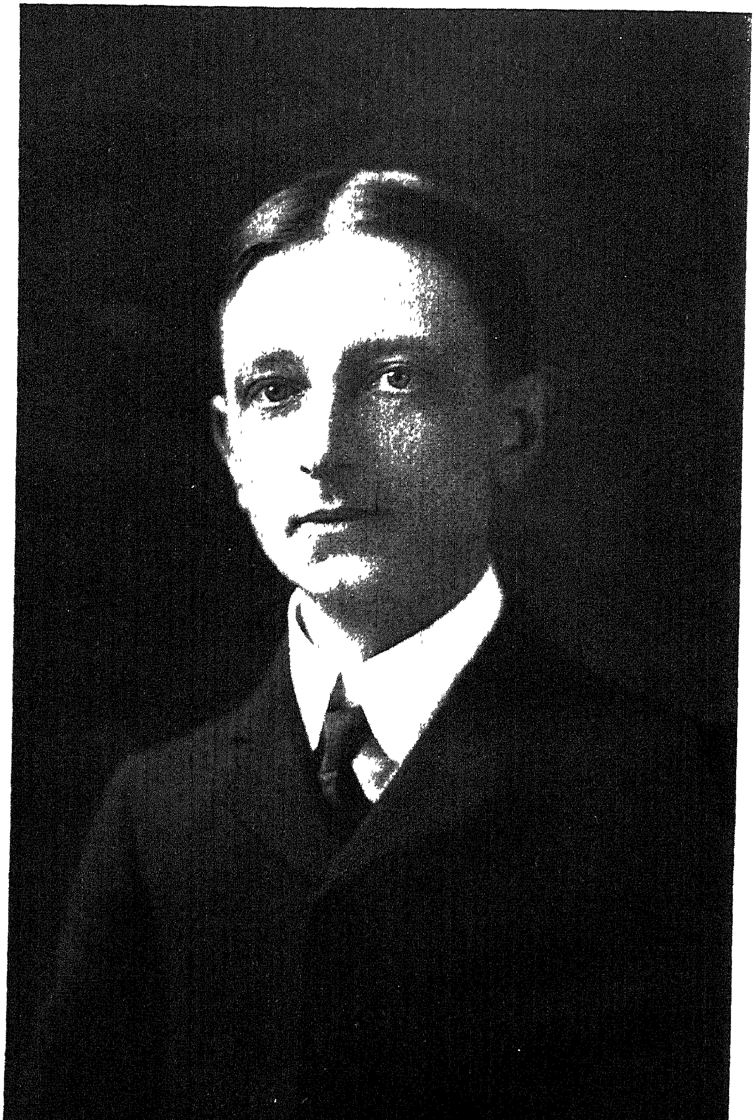
General F. V. Abbot writes regarding the matter as follows:

". . . During the heated debate in the Senate over the location of the canal, the celebrated controversy between advocates of the Nicaragua Route, and the Panama Route, my father took an exceedingly active part. Senator Morgan was the energetic proponent of the former route, and Senator Spooner of the latter. Mr. Taft was strong for Panama, and my father kept him supplied with much ammunition for presentation to the Senate. About this time my father met Senator Mark Hanna, he convinced that powerful man of the superiority of the Panama Route, and this occurring at the most critical time of the debate had great bearing on the adoption of the Spooner Amendment, over the most strenuous opposition of Senator Morgan. My father had a number of hearings before the Senate Committee on Isthmian Canals, which make interesting reading. The amendment was adopted by a vote rather late in the day. That afternoon I was walking up Connecticut Avenue, in company with General Mackenzie, leading my bicycle, when Secretary Taft and Mrs. Taft came up from behind us, and the Secretary called to me to come alongside of his carriage. Not knowing what in the world to do with a bicycle when talking to a Secretary of War, I handed it to General Mackenzie to hold, and ran out into the Avenue. The Secretary leaned over to me and said, 'Colonel Abbot, I have just received a telephone message from the Capitol that the Spooner Amendment has just passed the Senate. Get on your wheel and take a message to that effect from me to your father, whose complete knowledge of the

big subject has enabled me to present the matter to the Senate Committee convincingly, and so to him is largely due the adoption of the Panama Route'."

Ten years later, in 1915, General H. L. Abbot was appointed member of a committee of the National Academy of Sciences to investigate, at the request of the President of the United States, the safety of the Culebra Cut. This, writes his daughter, was "one of the real satisfactions of his life. At the age of 84 down he went alone, lugging a heavy bag of Canal documents. First by train to New York; then one night at Fred's; then by train to New Orleans, and steamer to the Isthmus. There followed busy days, not wasted either. He spent one day inspecting from 7:15 a. m. to 5 p. m., and then closed with an evening session of the Commission for good measure. He came home none the worse to a temperature of 8° Fahrenheit, and did not even take cold! I always like to remember that episode."

Thus in the enjoyment of one of the great satisfactions of his life we take leave of this strong, patriotic, able, diligent, influential man, who, having served his country 41 years in military life, served her surpassingly well for 20 years more as a great engineer.



H. A. Bumstead

NATIONAL ACADEMY OF SCIENCES

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BIOGRAPHICAL MEMOIRS

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OF

HENRY ANDREWS BUMSTEAD

1870-1920

BY

LEIGH PAGE

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1929

HENRY ANDREWS BUMSTEAD

BY LEIGH PAGE

Henry Andrews Bumstead was born in the small town of Pekin, Illinois, on March 12th, 1870, son of Samuel Josiah Bumstead and Sarah Ellen Seiwell. His father, who was a physician of considerable local prominence, had graduated from the medical school in Philadelphia and was one of the first American students of medicine to go to Vienna to complete his studies. While the family was in Vienna, Bumstead, then a child three years of age, learned to speak German as fluently as he spoke English, an accomplishment which was to prove valuable to him in his subsequent career.

Bumstead was descended from an old New England family which traces its origin to Thomas Bumstead, a native of England, who settled in Boston, Massachusetts, about 1640. Many of his ancestors were engaged in the professions, his paternal grandfather, the Reverend Samuel Andrews Bumstead, being a graduate of Princeton Theological Seminary and a minister in active service. From them he inherited a keen mind and an unusually retentive memory. It is related that long before he had learned to read, his Sunday school teacher surprised his mother by complimenting her on the ease with which her son had rendered the Sunday lesson. It turned out that his mother made a habit of reading the lesson to Bumstead before he left for school, and the child's remarkable performance there was due to his ability to hold in his memory every word of the lesson after hearing it read to him a single time.

Unfortunately Bumstead was never robust physically. Even as a child he suffered from hay fever and indigestion and his early schooling was delayed and interrupted by poor health. In 1911 he underwent a serious operation for gastric ulcer, and the arduous labor of planning and supervising the erection of the new Sloane Physics Laboratory at Yale the year after brought on a recurrence of the former trouble and the necessity

of a second operation in 1913. Only by taking continual care of his health and avoiding over-exertion of any kind was he able to accomplish what he did in science and in public service. Even so his achievement would have been much curtailed and probably his life itself shortened had he been denied the capable assistance of his wife. She took on her own strong shoulders all the financial and domestic worries of the household and the children and made his home at all times a haven of peace and rest.

Bumstead's early education was obtained at the Decatur, Illinois, High School, from which he went to Johns Hopkins in 1887, expecting to study medicine and to enter his father's profession. Courses taken under Fabian Franklin, however, turned his attention to mathematics and the influence of Rowland so stimulated the interest in physics which he had already shown that by the time he had completed his three years of undergraduate study he had definitely decided to devote his life to that science. After receiving his B. A. degree in 1891, he remained in Baltimore for two years as an assistant in the physics laboratory, taking as much graduate work as time would allow. Notebooks found among his effects show that he took a course in Thermodynamics under Rowland in 1891 which included, in addition to the classical thermodynamics, a considerable amount of the material contained in Josiah Willard Gibbs' great work "On the Equilibrium of Heterogeneous Substances." The following year he attended Rowland's lectures on Electrostatics and on the Electromagnetic Theory of Light.

In 1893 Bumstead was brought to Yale by Professor Charles S. Hastings as an instructor in the Sheffield Scientific School. Undoubtedly the prospect of coming into personal contact with Gibbs had much to do with his decision to make the move. What time he could spare from his teaching duties he devoted to continuing his study of physics in the Yale Graduate School. He took courses with Gibbs in Vector Analysis, Multiple Algebra, Thermodynamics, and Electromagnetic Theory of Light, his notes on the last two courses being extant and in the possession of the writer. Gibbs' high opinion of his brilliant student is evidenced by the notation "excellent" in the reports submitted to the graduate school at the termination of each of these

courses. Evidently Bumstead's keenness of perception was thoroughly appreciated by Gibbs, for the latter once remarked to one of his colleagues "Some things come easier to Bumstead than to most men."

Bumstead obtained his doctor's degree in 1897, submitting as thesis a paper entitled "A Comparison of Electrodynamic Theories." This work, although inspired by his contact with Rowland and Gibbs, was carried to completion with little aid from his supervisors and represents a more original contribution than is generally the case with doctor's theses. Unfortunately it does not seem to have been published, the only copy in existence being the manuscript in the author's own handwriting which has been preserved in the archives of the Yale library. In it Bumstead gives a critical survey of the electrodynamic theories in vogue at the time at which it was written. He states in the introduction that his principal object is "to set forth the true position of the experiments of Hertz in the history of the development of our knowledge of electricity; and to trace, in some measure, the influence of Helmholtz in the establishment of the true theory of electrodynamics,—an influence which was second only to that of Maxwell." Throughout the mathematical part of this essay the author uses Gibbs' significant vector symbols in place of the clumsy European notation of parentheses, brackets, grads, divs and curls. In view of the simple and unambiguous electron theory of Lorentz which has since put the subject of electrodynamics on a firm basis it is interesting to note the author's reference to "the multiplicity of electrodynamic theories and their wide differences as to physical basis and fundamental mathematical formulæ."

After an analysis of Ampère's and Grassmann's theories, he makes a critical comparison of the potential theories developed by Neumann, Weber and Helmholtz. The very general form of Helmholtz's theory appealed to him strongly, and he takes delight in showing how it contains as special cases most of the other theories proposed, including Maxwell's mathematical formulation of the results of Faraday's researches. While Helmholtz's attempts to discriminate experimentally between various discordant viewpoints did not seem to him conclusive,

his admiration for Hertz's genius as an experimenter knew no bounds. He lays particular emphasis on Hertz's zeal in following up every unexplained phenomenon to its source, mentioning in particular the discovery of the effect of ultra-violet light on the conductivity of the spark gap. The influence of the British school of physicists is very evident in the point of view adopted in this paper, and it is clear that at this date the "ether" was very real to the author.

In 1900 Bumstead was promoted to an assistant professorship, and six years later he left the Sheffield Scientific School to succeed Professor Arthur W. Wright as Professor of Physics in Yale College and Director of the Sloane Physics Laboratory. The year before receiving his doctor's degree he married Luetta Ullrich, daughter of John Ullrich, a banker of Decatur, Illinois. A son, John Henry, was born in 1897 and a daughter, Eleanor, in 1902. The son has adopted the profession of his grandfather, having obtained his M. D. at Johns Hopkins University in 1923 and being at present connected with the Yale Medical School.

Bumstead's heavy teaching duties during the five years following the completion of his doctor's thesis left him little time for research. His interest in electrodynamics, however, was always keen, and in 1902 he published a short paper in which he showed how Maxwell's equations completely accounted for an anomaly in the reflection of electric waves which had been causing some discussion among his contemporaries. If standing waves are set up on a pair of parallel guide wires terminating in a conducting plane at right angles to their length, the node in electric intensity found at the end of the wires is at a distance from the nearest node on the wires agreeing with the distance between other adjacent nodes. If, however, the conducting plane is removed, the loop to be expected at the free end of the wires is found to be at a distance from the nearest node somewhat less than a quarter wave-length. Bumstead showed that the introduction of a fictitious magnetic conductivity into Maxwell's equations established a close correspondence between this case and the well-understood arrangement in which the ends of the parallel conductors are united by a short connecting wire.

The death of Gibbs the year following the publication of this paper brought to Bumstead the sad duty of writing the obituary of his friend and teacher. His broad knowledge of mathematical physics and his intimate association with Gibbs over a number of years enabled him to prepare an appreciation of the great physicist which could have been equalled by few of his contemporaries. The tribute to the personal character of Gibbs which forms the final paragraph of his article is worth quoting since it applies so well to Bumstead himself:

"Unassuming in manner, genial and kindly in his intercourse with his fellow-men, never showing impatience or irritation, devoid of personal ambition of the baser sort or of the slightest desire to exalt himself, he went far toward realizing the ideal of the unselfish, Christian gentleman. In the minds of those who knew him, the greatness of his intellectual achievements will never overshadow the beauty and dignity of his life."

While Gibbs' "Elementary Principles in Statistical Mechanics" had been published as one of the Yale Bicentennial Series in 1902 and E. B. Wilson had put in the form of a book Gibbs' lectures on vector analysis, many of the great physicist's papers were available only in journals not readily accessible. So Bumstead, in collaboration with Gibbs' nephew, R. G. Van Name, edited and published in 1906 his former teacher's Scientific Papers. The edition printed at that time has already been exhausted, but thanks to a generous admirer of Gibbs funds have recently become available to reprint the Scientific Papers and the Statistical Mechanics and to make possible the publication of two volumes of commentaries. The latter are now being prepared under the editorial supervision of Haas in Vienna and Donnan in London.

During the early years of the present century Sir J. J. Thomson's investigations of the properties of cathode rays and of gaseous ions were attracting more attention among physicists than any other line of experimental research. Bumstead was greatly interested in this work and it was largely through his efforts that the successor of Maxwell and Rayleigh was persuaded to come to Yale to deliver the first Silliman lectures in May, 1903. While in New Haven Professor Thomson told him

of the work being done at the Cavendish Laboratory on a radioactive gas found in water coming from deep levels, and suggested work of a similar nature at New Haven. This Bumstead carried out in collaboration with his colleague L. P. Wheeler. They found evidences of radioactivity not only in gas driven off from water obtained from a well 1500 feet deep near New Milford, Conn., but also in that boiled off from surface water drawn from one of the New Haven city reservoirs. Comparison of the rate of decay of the soil-water gas with that of radium emanation (radon) showed the two to be identical. The rate of diffusion of the emanation through a porous plug was then investigated, and found to be about four times that of carbon dioxide. This determination led to an atomic weight of 180, which was, perhaps, the most reliable value which had been obtained up to that time, and, considering the difficulties of the experiment, surprisingly close to the values yielded by later more accurate methods.

Bumstead secured leave of absence from Yale for the college year 1904-1905 in order to devote his entire time to study and research at the Cavendish Laboratory in Cambridge. During this winter he took the opportunity of attending Sir Joseph Larmor's lectures on Electrodynamics and completed two experimental researches. The second of these, on the heating effects produced by Röntgen rays in metals, aroused a great deal of interest among scientists. This investigation was undertaken at a time when the attention of the scientific world was focused on the brilliant researches of Rutherford on atomic disintegration. Particular interest was being given to the attempt to hasten or retard radioactive disintegration by varying external conditions, and to the search for new sources of radioactivity. However, every effort to control the rate of decay seemed to be in vain. From the lowest to the highest extremes of temperature, under all conditions of electromagnetic excitation, radioactive transformation went on at the same invariable rate. Bumstead's research consisted in measuring the heat produced in lead and in zinc when Röntgen rays are equally absorbed in the two metals. His experiments seemed to lead to the surprising result that the heat developed in lead is approximately double

that produced in zinc. The only plausible explanation seemed to be that the rays effected a disintegration of the lead atoms on which they impinged, liberating energy which was then converted into heat. This conclusion, if true, would have indicated a most important discovery: the artificial disintegration of atoms under the incidence of X-rays. Unfortunately the subsequent work of Angerer and of Bumstead himself failed to confirm the earlier results. By varying the conditions of the experiment Bumstead was able to show that the differential effect observed in the first instance was due to inadequate heat-insulation of the metals under investigation.

During this winter in England Bumstead had come into intimate contact with many British scientists, including Lodge, Darwin and Rayleigh in addition to J. J. Thomson and Larmor. His lovable character and versatile mind made him a friend much esteemed by all who knew him. During the summer of 1905 he joined E. F. Nichols and Duane on a trip through Holland and Germany, where many famous physical laboratories were visited and the travelers were entertained by a number of their European colleagues.

Shortly after Bumstead's return to New Haven he was offered a professorship in both the Sheffield Scientific School and Yale College. As Professor A. W. Wright was retiring from the faculty of Yale College, Bumstead felt that the need for him there was greater than in the Scientific School. Therefore he accepted the position offered by the College and succeeded Wright as director of the old Sloane Laboratory. At that time the physics departments in the College and in the Scientific School were entirely distinct, each having its own staff and the two being housed in separate buildings half a mile apart. Only in connection with the instruction of graduate students and at meetings of the Journal Club or when papers were presented at the Physics Club, which had been founded by Gibbs, did the two departments come together. Impressed by the anomaly of the situation and realizing the inadequacy of the College physics laboratory and of the yet more cramped quarters of the department in the Scientific School, Bumstead made every effort to effect a union of the two departments and to secure better

laboratory facilities. It was largely as a result of these efforts that William D. Sloane and Henry T. Sloane of New York were led to give to the University and to endow generously the present commodious building which was completed in 1912. All those who have benefited by the facilities and conveniences of the new laboratory are under a great debt of gratitude to Professor Bumstead for his many months of painstaking planning and careful supervision of the erection of the building. In this new laboratory were housed together, for the first time, both undergraduate departments of study in a single subject. This union was the forerunner of the departmentalization which was so prominent a feature of the University reorganization undertaken at the close of the war. A few years after the opening of the new laboratory Bumstead was instrumental in introducing into the undergraduate curriculum honors courses patterned after those at Oxford and Cambridge. For many years he personally conducted the honors classes in physics, which were deservedly popular among the more serious minded students.

In 1905 appeared Einstein's first paper on relativity in which he proposed the principle which now bears the name of "special" or "restricted" relativity. This paper greatly stimulated Bumstead's ever-present interest in electromagnetic theories, and led him to publish in 1908 a critical comparison of the view-points of Einstein and Lorentz. Among other things he devised elegant methods of deducing some of the consequences of the relativity principle. In particular, mention should be made of his derivation of the ratio of longitudinal to transverse mass from a simple consideration of the period of a moving torsion pendulum. Furthermore, he made an attempt to extend Einstein's method to gravitational problems, and pointed out clearly the fallacy of the oft-repeated assertion that a finite velocity of propagation of gravitational force should lead to a first order perturbation in planetary orbits.

Although geatly impressed by the beauty and symmetry of Einstein's theory, the ether had such a real significance to Bumstead that he was never able to accept completely the view-point of the relativist. He believed in holding close to the facts revealed by experimentation, and he often stressed the point that

all physical laws are the result of experimental discoveries and that no mathematical formulation can contain more than is involved in its premises. Therefore he doubted the value of Einstein's new principle in opening up unexplored fields of research. To him it seemed a closed discipline, perfect but infertile. Hence Einstein's ultimate success in generalizing the principle, so as to make possible the application of the equivalence hypothesis to gravitational fields, appealed to him all the more as a great work of genius.

In 1911 Bumstead began an investigation of the delta rays emitted by metals under the action of alpha rays, a study which he continued for the following three years. Delta rays—so named by J. J. Thomson—are the slow moving electrons detached from metallic surfaces under the bombardment of the more massive alpha particles. The ionization curves obtained by Bumstead show all the characteristics of the Bragg curve for gases, but, unlike the latter, the curves for different metals have very nearly the same form. This observation led him to suspect that delta rays come from a gas adsorbed on the metal surface rather than from the metal itself. An investigation of the velocities of the particles constituting the rays revealed the fact that some of them have velocities corresponding to a potential difference as great as 2000 volts. These swifter rays seem to be the primary result of the impact of alpha rays, and to give rise to secondary slow-moving electrons when they collide with other atoms.

The results of these experiments suggested to him that the impact of alpha particles might cause high speed electrons to be emitted as well by gaseous molecules in the free state. To test this point he brought home from England on his trip in 1914 an expansion apparatus made by the Cambridge Scientific Instrument Company after C. T. R. Wilson's design. This apparatus he modified so as to enable him to work in hydrogen at pressures between 90 and 100 mm., and with it he obtained a number of photographs of alpha ray tracks which showed very clearly electronic trails radiating from the column. These trails supplied the evidence of high speed delta rays for which he was searching.

Following his second operation in 1913 Bumstead's health

made necessary a respite from academic duties. Consequently he obtained a year's leave of absence and took his family abroad in the summer of 1913. After passing through Italy, Switzerland and France he settled in Germany for the winter. While there he was greatly puzzled by the change in attitude of his friends among German scientists. Their cordiality to him was as warm as on the occasion of his visit in 1905, they were eager to entertain Mrs. Bumstead and himself at tea or dinner, but to all suggestions that he would like again to visit their laboratories they turned a deaf ear. Whereas in 1905 he was welcome in every German physical laboratory that he cared to visit, in 1914 he did not succeed in passing through the doors of one. Not until August did he fully realize the meaning of this change.

Leaving Germany in the Spring he went to Cambridge and was in England at the outbreak of the war. There men of science were petitioning the government to avoid war at all costs. In a few days time Germany's invasion of Belgium caused a revulsion in public opinion, and the same scientists who had been deploring war urged their government to join France and Belgium without delay.

In the stress of the early days of war it was with difficulty that accommodations were secured for the return voyage to the United States. Although his country was not an active participant Bumstead found the minds of his friends at home filled with indignation and apprehension as to the future. In his own mind there was but one course for his country to pursue, and at every opportunity he urged the importance of joining the Allies at the earliest possible moment. When finally the people of the United States, aroused by the ruthless sinking of the Lusitania, declared war with Germany, he placed all his time and ability at the service of his country. During 1917 he was a member of the national committee appointed to examine the merits of proposed anti-submarine devices, and he took an active part in the experimental development of such devices which was carried on at New London.

The distance of the seat of government of the United States from the capitals of her allies and from the scene of hostilities made it difficult to meet promptly the requirements of the

officers in the field and to cooperate as closely as was desirable with the governmental agencies of England and France. In a war in which scientific devices played such an important part it was vital to secure rapid interchange of ideas and to supply each one of the associated powers with immediate information of the technical advances made by the others. For this purpose it was decided to locate a liaison officer at London who would command the confidence of British and French scientists, and who could acquire and transmit to Washington information without the delay and red tape inherent in diplomatic channels of communication. Bumstead, on account of his broad scientific knowledge, his wide circle of friends among British men of science, and not least on account of his tact and discernment in dealing with others, was an ideal candidate for such a post, and in February, 1918, he sailed for London as Scientific Attaché to the American Embassy. Immediately upon his arrival Admiral Sims put office space and stenographers at his disposal, and due to this hearty cooperation he was able to start his work with the minimum of delay. He quickly made points of contact with scientific workers in Great Britain and in a very short time the desired technical information was flowing rapidly and steadily to Washington. In fact his position and his relations with those at home enabled him to return the many kindnesses shown him by officers of the Navy by securing for them in several instances needed information more speedily than it could have been obtained through the official channels of the Navy Department.

In a letter home Bumstead gives an account of his first air raid, which occurred early in March, 1918:

"Last night I experienced my first air raid; it was something of a novelty even to Londoners, since there was no moon. The guns gave the warning just after I had gone to bed. I got up and looked out of the windows but could see nothing except some distant flashes in the sky and, as it was cold, I went back to bed. No bombs were dropped anywhere near here, so I did not hear them; if I had I am sure I should have been much frightened. As it was I heard only the firing of the defensive barrage and the bursting of the shrapnel high in the air. It sounded just

like the Italian who was 'cured by miracles,' only there was more of it. So I was not in the least frightened, but was surprised to find that I was thoroughly enraged and filled with hate for the infernal Germans when I thought of what must be happening somewhere in London. It was a much more intense and violent feeling than I have ever experienced when reading about their various atrocities. It is curious that actual physical proximity makes a difference. Just as when I first saw wounded soldiers at Liverpool, I had a much stronger feeling of pity and sorrow than I had got from reading about them."

Not only did his friends among British men of science facilitate his mission through their connections with the research staffs of the Munitions Inventions Department and of Woolwich Arsenal, but they brightened his leisure hours by week-end invitations, luncheons and dinners. In his letters he mentions a week-end at Trinity Lodge shortly after the induction of Sir J. J. Thomson into the office of Master of Trinity, and speaks of other week-ends spent with Ambassador and Mrs. Page, with the Jeanses, Schusters, Braggs, and Rayleighs. On two occasions he dined with Sir Joseph Larmor at the House of Commons, and Sir J. J. Thomson introduced him into the exclusive Athenaeum Club. In a letter to Mrs. Bumstead he says:

"I have been received absolutely with open arms by every single Britisher I've come in contact with—not only the actual scientific workers, but the officers and officials who have charge of such work. There is not the slightest holding back and they welcome enthusiastically the idea of direct communication between the scientific workers."

He was planning to extend his activities and had already arranged for one of his colleagues at Yale to join him in London as his assistant when it became evident that the war was coming to a close and that an armistice could not be more than a few weeks distant. It required a few months after the close of hostilities to disband his organization and it was not until February, 1919, that he returned to New Haven to resume his duties at the University.

The peace-time routine of teaching and conducting research at Yale had been seriously deranged by the war. Undergraduates had left in large numbers before completing their courses to enter the army or the navy, regular classes had dwindled in size, many of the faculty had obtained leaves of absence to engage in war work and those who remained had dropped their normal research to devote themselves to training officers for various branches of the service. The staff of the physics department, in particular, had been engaged in supplying officers of the signal corps with intensive training in radio communication. Under these conditions the abrupt ending of the war and the necessity of returning to a normal basis provided an excellent opportunity for effecting a reorganization, the need for which had been felt for some time. On his return to New Haven Bumstead found the University engaged in reviewing the situation and in making plans for a future of greater usefulness and service. His remarkable power of coordinating the divergent viewpoints of others and his excellent judgment made him much in demand as a member of the faculty committees which were moulding the new Yale. He gave freely of his time and his strength to this service, in spite of his desire for the opportunity to devote himself to a life of quiet study and research.

The war having emphasized the value of research in all fields of human activity, far-sighted and patriotic donors had provided the National Research Council with generous funds to promote scientific investigation. Committees were organized to prepare reports on various phases of research in order to acquaint investigators more rapidly with current progress and to suggest to them new points of attack. Bumstead was appointed chairman of one of the first of these committees—that on Atomic Structure. While the pressure of other duties forced him to sever his connection with the committee before its work was completed and while he did not partake personally in the writing of its report, his leadership and advice were invaluable to the other members of the group.

Bumstead's activities in connection with the reorganization of the University had taken so much of his time during the

college year 1919-20 that he had been seen little in the physics laboratory except during the hours when he was engaged in lecturing. This labor ended, he was planning a resumption of experimental research when the call came to succeed James Rowland Angell—president-elect of Yale—as chairman of the National Research Council. The incumbent of this position was changed annually, so his acceptance would necessitate only a single year's leave of absence from Yale, and he did not feel justified in refusing the opportunity of a wider service. His administrative ability and his power of inspiring the loyalty and best efforts of others made his success in his new position a certainty.

Bumstead's residence in Washington did not preclude occasional visits to New Haven, and on one of these (October 21, 1920) he contributed a lecture on the History of Physics to the series on the History of Science which had been planned under the auspices of the Yale Chapter of Gamma Alpha. In reading this lecture—and this statement is true of all his publications—one is impressed with his broad knowledge of science, his lucid style and his deep insight. Tracing the progress of physics from Galileo to Planck and Einstein he uses as his motif the rise and increase in number of the "imponderables" to a state of maximum significance during the nineteenth century, followed by an increasing doubt as to their reality or even importance and the gradual rejection of one after another.

Unfortunately Bumstead was not destined to live out his term of office as chairman of the National Research Council. The day after Christmas, 1920, he took train for Chicago to attend the annual meeting of the American Physical Society. During the first two days of the session the windy city did her best tc discourage her visitors with high gales and bitter cold. Nevertheless, to his many friends who talked with him there Bumstead appeared to be at the height of mental and bodily vigor. On Wednesday evening he attended a meeting of the National Research committee of which he had been chairman, and contributed his keen analysis to the discussion until almost midnight. The morning of Friday, December 31, he spent with R. A. Millikan, at whose home he had been staying, in going

over the research work of the Ryerson Laboratory. He left Millikan about 11:30 and started on the return trip to Washington in the early afternoon. During the evening he mentioned a feeling of fatigue to friends on the train and decided to retire early. The next morning his friends were surprised at his absence from breakfast in the dining car, and one of them—Dr. Vernon Kellogg—went back to his berth to ascertain if he had been taken ill during the night. The curtains before the berth were still closed; on pulling them apart Dr. Kellogg found him dead. Apparently he had passed away from heart failure during his sleep.

Recognition of Bumstead's eminence as a scientist has come from many sources. Long a fellow of the American Physical Society he was a member of the board of editors of its official publication, "The Physical Review," from 1914 to 1916 and succeeded R. A. Millikan as president of the society in 1918. He became a fellow of the American Association for the Advancement of Science in 1910 and vice-president of Section B in 1916. Retiring from this office in 1917 he delivered the vice-presidential address at the Christmas meeting in Pittsburgh, choosing for his title "Present Tendencies in Theoretical Physics." In this speech he emphasized the demoralizing effect of war upon research in pure science, noting the absence of progress in both theoretical and experimental physics since August, 1914. The address is a succinct summary of the history of theoretical physics from Newton to Einstein and Bohr, ending with a prediction of great advances in the future as a result of the effort to reconcile the many apparently discordant and mutually contradictory elements which had been revealed by the study of radiation and atomic structure.

In 1913 Bumstead was elected a member of the National Academy of Sciences, an honor conferred only upon the foremost of American scientists. He was a fellow of the American Academy of Arts and Sciences, and a member of the American Philosophical Society and of the Connecticut Academy of Arts and Sciences. The University of Toronto conferred on him the honorary degree of Doctor of Science the June preceding his death.

Not only was Bumstead's advice always in demand on the part of his scientific associates, but it was frequently sought by those whose interests lay outside the domain of science. As an example may be cited Henry Adams' request for a critical opinion of those chapters of "The Degradation of the Democratic Dogma" which contain the author's bold excursion into the scientific method. Bumstead pointed out the dimensional difficulties involved in applying the "law of squares" to historical phases, and repeated his criticism to Brooks Adams when the latter was preparing his deceased brother's manuscript for publication. However, the importance of this hypothesis to the argument of the essay was sufficient in the eyes of the editor to warrant its retention in spite of its obvious fallacy.

In addition to the papers published under his own name, Bumstead supplied most of the underlying ideas and much of the motive force responsible for the great majority of the doctor's theses in physics coming from Yale during his association with the University. He was always generous in giving his time and ideas to others, and never asked the students who worked under him to share with him the credit of authorship. On several occasions his interest and kindness of heart led him to supply pecuniary aid from his own pocket to needy graduate students in the department.

In view of his extensive knowledge of theoretical physics and his high attainments as a mathematician it is rather surprising that Bumstead's research was mostly confined to the experimental side of his subject. In fact, half of the theoretical papers which he published were more of the nature of critiques than of new theoretical developments. Perhaps the explanation lies in the feeling he often expressed that experimentation is the real business of the physicist and in a certain distrust of speculative ideas which he frequently manifested.

Bumstead's power as a teacher was perhaps even greater than his ability as an investigator. His insight and his deep understanding of his subject made his lectures on Electrodynamics and Electromagnetic Theory of Light the inspiration of the graduate work in physics at Yale. He was never too busy or too hurried to spend an hour discussing a knotty problem with

a member of his class. His illuminating discussions at meetings of the Journal Club or of the Physics Club were eagerly looked forward to by students and colleagues alike.

Eminent as a scientist, inspiring as a teacher, in his personal character he was the embodiment of the perfect Christian gentleman. Modest regarding his own achievements, cheery in his attitude toward life, always ready to lend a helping hand, unfailing in his interest in the work and ideas of others, never backward in bestowing praise when he felt it was deserved, he was loved by his students, his colleagues and all those who had the good fortune to pass his way. His high ideals, in human relationship as well as in scientific attainment, have had a profound influence in moulding the characters of the young men whom he has trained. President Arthur T. Hadley summed up the feeling of the Yale community when he said, in speaking of Professor Bumstead's death:

"His charm as a man will live in the memory of his friends here longer even than the great things he accomplished in physics. No man in the whole faculty of Yale was more universally loved and admired."

RESOLUTION PASSED BY THE INTERIM COMMITTEE OF THE NATIONAL RESEARCH COUNCIL, JANUARY 3, 1921.

RESOLVED, That the National Research Council learns of the death of Dr. Henry A. Bumstead, chairman of the Council, with great sorrow and profound sense of loss. Dr. Bumstead in his association with the Council had revealed to its officers and members not only a high capacity for administration, and a most loyal fidelity to the aims and work of the Council, but also a sweetness of disposition and personal attractiveness which had won for him the devoted and affectionate regard of all of his colleagues in the Council. In his death the Council and the scientific world lose a man of most eminent attainments, highest character, and lovable personality.

The National Research Council extends to the bereaved wife and family its deepest sympathy and condolence and wishes to express to them its full appreciation of the great value of the services which Dr. Bumstead rendered it in the period of his association with it and the great loss which it suffers by his untimely death. But may we all remember that "that life is long that answers life's great ends."

FROM SCIENCE, JANUARY 28, 1921
(Abridged)

My personal acquaintance with Henry A. Bumstead dates from a meeting of the British Association in Winnipeg in the summer of 1909.

He had studied in Cambridge, England, where his engaging personality, keen intelligence, and unusual *savoir faire* had made him a place in the hearts and homes of English scientists which has been held by few Americans. I was then almost unknown both to him and to them, but I soon learned that if Bumstead was in any gathering I should at once feel at home

I was walking with him one day through one of the busy streets of Winnipeg when he asked if I would not step into a shop with him while he bought a little memento for Mrs. Bumstead, a "bad habit" which he said he had formed on trips away from home.

I mention these two trivial incidents because they reveal the soul and heart of the man, and what, after all, is either science or art in comparison?

When in 1917 the important and difficult post of scientific attaché in London was created, Bumstead was the only man considered, for no scientist in this country had his tact, his judgment, his knowledge of England, and his ability to assist in bringing about what was then, and what is now, the most important need of the modern world, namely the cooperation and mutual understanding of the two great branches of the Anglo-Saxon race.

Bumstead's success in London was extraordinary. The British liked and trusted him. Admiral Sims and our own War Department placed large responsibilities upon him, and his office became the center of a very active and very important service. Young American officers who went abroad on scientific missions found him the center of their contacts and the prime source of their usefulness. They all became his devoted admirers. Not one or two but a dozen or more of both British and American officers who came to Washington during the war told me that they owed their success in their work in England and the continent primarily to Bumstead, and counted it the most valuable part of their experience that they had had an opportunity to become acquainted with him. One of these officers described him as the most influential American in England.

As chairman of the National Research Council, as member of the National Research Fellowship Board, and as participant in other important groups with which he was associated at the time of his death, Bumstead showed the same broad outlook, the same big human interest, the same tact, the same sane intelligence and sound judgment which had characterized his work in England.

. . . .

He leaves a big gap in the ranks of American physicists. . . . He had a brilliant analytical mind, profound scholarship, exceptional critical capacity, excellent judgment, an extraordinary winsome personality, the finest culture, and a great heart. His personal scientific contributions were important, though they had been much interfered with by his none too rugged health. His effect upon American physics, how-

ever, was not limited to his own scientific papers, but he exerted a powerful influence upon his pupils and upon his fellow physicists.

It is not merely American science, however, which can ill afford to lose him twenty years before his time. American life in all its aspects is sadly in need of men of Bumstead's type. The cause of sanity, of culture, of Anglo-Saxon solidarity, of scholarship, of science, of world civilization, all suffer irreparably through his death.

ROBERT A. MILLIKAN.

FROM THE YALE ALUMNI WEEKLY, MARCH 18, 1921
(Abridged)

As a teacher, he (Bumstead) showed . . . . a rare power of lucid exposition and an unusual ability to understand the difficulties of the student in grasping novel and abstruse concepts. . . . . Every one of the fortunate five hundred (who took his courses) would rank him among the greatest teachers of whom Yale boasts.

During his entire career, Bumstead was active in performing and instigating research. . . . He made important contributions to our knowledge of atmospheric radioactivity and to the understanding of some of the puzzling phenomena in the conduction of electricity through high vacua. In addition to the work in print under his own name, there is a great deal in the published work of his students and colleagues which owes much to his insight and inspiration. And his influence on research extended beyond the walls of the University. In the American Physical Society, in the American Association for the Advancement of Science, in the National Academy of Sciences and its Research Council, he exerted a profound influence on research in the fundamental sciences which was national in its extent.

It is impossible to give in any reasonable compass an adequate picture of such a man. Great as was his achievement, the man was larger than his work. The University and the world of science have lost a leader notable for qualities of heart as well as of mind, which were never more needed in the nation than at the present time. A teacher with the power to make the student see for himself; a councilor wise, broad-minded and far-sighted; an administrator with the ability to make the practicable policy achieve the ends of an ideal. His friends, the University, the world of science, and the nation at large are at once the poorer in his loss and the richer in the heritage of his memory.

LYNDE P. WHEELER.

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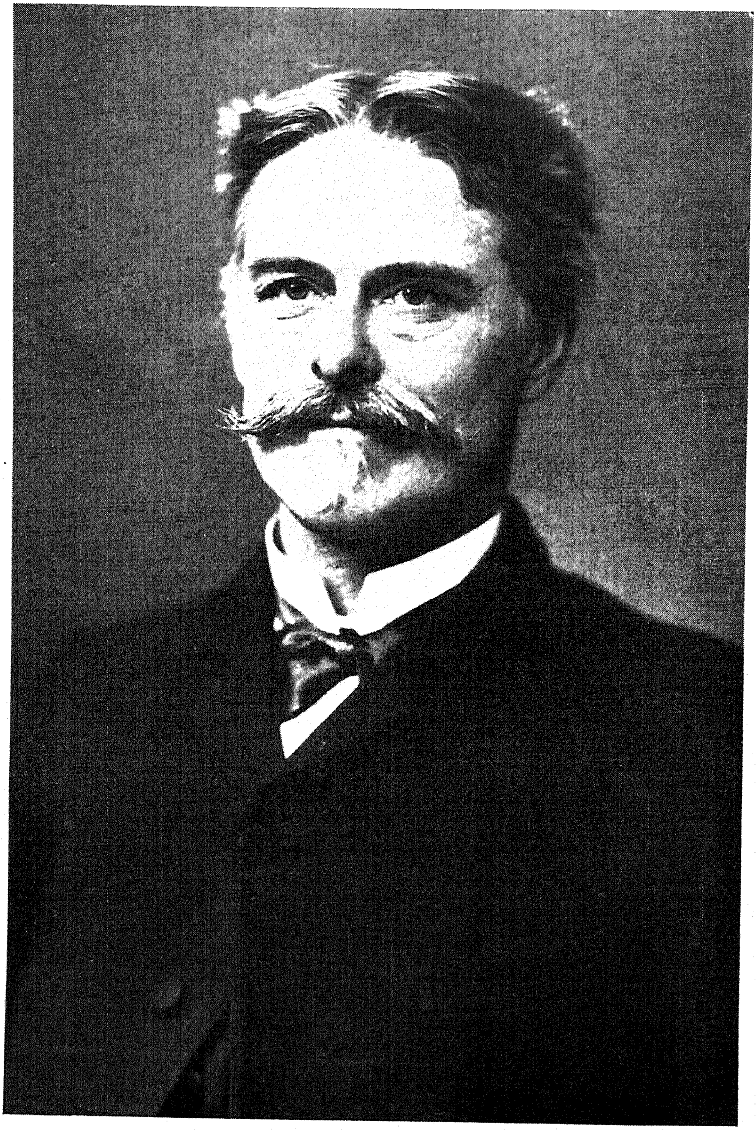

E. D. Cope

NATIONAL ACADEMY OF SCIENCES

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BIOGRAPHICAL MEMOIRS

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OF

EDWARD DRINKER COPE
1840-1897

BY

HENRY FAIRFIELD OSBORN

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1929

CONTENTS

LETTER OF TRANSMISSION

January the thirtieth,
Nineteen hundred twenty-nine

Edward Drinker Cope, one of the greatest palaeontologists and anatomists America has produced, died on April 12, 1897. Sometime before his death his secretary, Miss Anna M. Brown, had begun work upon his extraordinarily extensive and difficult bibliography. These materials passed into my hands together with a nearly complete set of Cope's writings and his two great collections of fossil vertebrates, including fishes, birds, reptiles and mammals, now in the American Museum of Natural History. Under my direction the bibliography was completely revised by Miss Jannette May Lucas and extensive scientific annotations were made by Dr. William Diller Matthew, Dr. W. B. Veazie, Dr. E. W. Gudger and Dr. William King Gregory. The portions concerning batrachians and reptiles have been verified by Dr. G. Kingsley Noble.

Shortly after Professor Cope's death, Persifor Frazer published a brief bibliography and biography. At the memorial meeting of the American Philosophical Society on November 12, 1897, a biographic symposium was held at which Theodore Gill reviewed Cope's work among the reptiles and fishes, while his contributions to geology and mammalogy were discussed by William Berryman Scott and myself. Appreciative, independent biographies were also written by Hosea Ballou, Marcus Benjamin, J. S. Kingsley and Persifor Frazer, by myself, and Miss Helen Dean King. The prolonged and intensive research into the extremely full life and works of Cope, in which I was first aided by Mrs. Hermann O. Mosenthal, dates back to 1897. This research was suspended for several years and then renewed with still deeper and more extensive research by Miss Helen Warren in the year 1928, continuing up to the present time.

Professor Cope's family has been warmly sympathetic in this

great undertaking and has generously donated to the Osborn Library of the American Museum, the entire family and scientific correspondence of Professor Cope, beginning with the diaries of his boyhood. Some members of Professor Cope's family at the instance of his daughter, Mrs. Julia Cope Collins, have generously contributed a sum to aid in this research, which has been partly sustained also by the Osborn Research and Publication fund of the American Museum of Natural History.

Thus step by step all the materials have been brought together and are now assembled in condensed form for the present Biographical Memoir of the National Academy of Sciences, prepared with the able aid of Mrs. Helen Warren Brown. It is expected that this relatively brief and concise biography of fourteen thousand words will be followed by a volume giving a more comprehensive account of the life and works of this man of remarkable genius.

The bibliography of Cope will be of incalculable value to all workers in vertebrate zoology and palaeontology, as well as in biology and philosophy, because it points out all the available sources, of both permanent and very fugitive character, in which may be found the outpourings of his lifelong observations and the brilliant series of generalizations which flowed from his creative mind.

HENRY FAIRFIELD OSBORN.

EDWARD DRINKER COPE

BY HENRY FAIRFIELD OSBORN

INTRODUCTION

Edward Drinker Cope was born in Philadelphia, the cradle of American philosophic and scientific thought, on July 28, 1840, grew up a contemporary of the palaeontology which Georges Cuvier had founded in 1799, and spent his life and a considerable fortune in its furtherance. Happening to be born with an observing and enquiring mind, he absorbed in childhood the stores of natural history painstakingly gathered by pioneer scientists of the sixteenth, seventeenth and eighteenth centuries, worked them over with genius, adding as he grew older a first hand acquaintance with the unbelievably ancient fossils discovered by fur-traders in the plains of Nebraska, Montana, Wyoming, Colorado, Kansas, New Mexico, Oregon and Texas, and proceeded to astonish his conservative predecessors by setting forth overwhelming evidence of the theory of evolution as traced from fossil through living forms, from the lowest single-celled organism to man.

Altogether he contributed more than 1,300 papers to scientific literature, making known more than 600 species and many genera of extinct vertebrates new to science, many of which he had personally discovered in the Cretaceous strata of Kansas or the Tertiary of Wyoming and Colorado. Among these were some of the oldest known mammalia, obtained in New Mexico where he had served with the United States Geological Survey under G. M. Wheeler in 1874. In 1885 Cope wrote with some satisfaction that he had traced successfully the primitive ancestry of the reptiles, birds and fish, back to their point of origin and that among the mammalia he had done the same thing for the deer, the camels, the musk, the horse, the tapir, the rhinoceros, the cats and dogs, lemurs and monkeys, and had important

evidence of the origin of man among the mammals.[1] The marsupials he had traced only in part and was also still baffled by the exact tree of the bears, elephants, hyenas and hogs.

Ancestry and Boyhood

The Copes of Philadelphia were Quakers, and like many members of the Pennsylvania Society of Friends, very prosperous. They were a branch of an old and distinguished Wiltshire family, one member of which, Oliver, having fallen upon hard times, bought some land from William Penn in 1687 and moved his family to America. They prospered and Oliver's great-grandson, Thomas Pim Cope, became in 1821 proprietor of the Cope line of packets running between Philadelphia and Liverpool. Alfred Cope, son of Thomas, was therefore able to live a more or less retired life in the family place "Fairfield" not far from Philadelphia and to indulge his love for cultivating fine trees, rare shrubs and flowers.

At Fairfield his son, Edward, was born in July 1840 and grew up under his father's tutelage. His early education although ostensibly aimed to make of him either a farmer or a ship-owner, when taken into relation with his strong natural bent, moulded him firmly into a man of science. He was taught the names, characteristics and proper care of the trees and plants under cultivation in his father's eight-acre farm. He was encouraged to observe the habits of the farmyard beasts and to keep pets. He was trained to make accurate maps, beginning with a diagram of the farm and branching out to the several states, the whole United States, the continent of North America, and finally the world. He learned a primary division of animals from his father:

Pigs have bristles,
Cows have hair,
Birds have feathers,
Snakes are bare.

[1] *Origin of Man and Other Vertebrates, Professor* Edward D. Cope, Popular Science Monthly, September, 1885.

He was also permitted, as he grew older, to use his father's library which included such natural history texts as Mark Catesby on the *Natural History of Carolina, Florida and the Bahama Islands*.

When he was six years old Edward was taken to a museum in Philadelphia, either Barnum's or the one in the Academy of Natural Sciences building. There he saw the Mastodon skeleton and Koch's disproportionate *Hydrarchus* (Zeuglodon), the water king, which had been constructed from the remains of three skeletons to the astonishing length of 114 feet. Stuffed monkeys, alligators and crocodiles were also on display and Edward wrote a full description of the trip to his grandmother, stating characteristically: "Does thee know what that is? I will tell thee." The following year the boy was taken to Boston on one of his grandfather's ships and wrote a little journal along the way, sketching in it starfish, dolphins and flying fish, as well as the Bunker Hill monument. A year or two later he was taken to Cuba and was evidently deeply impressed by the tropical scenery; when he was seventeen he wrote from memory a very vivid description of a ride along a southern beach, skirting a most convincing jungle and palm trees. When he was about nine years old he was sent to school in Philadelphia and his visits to the Academy Museum became frequent. He went alone or with school-fellows and kept careful account of what he had seen, often illustrating by sketches of the animals his attempts at classification by name and characteristics. At thirteen, in 1853, he was sent to the Friends Select School at Westtown, Pennsylvania, where his lessons were usually well reported but the conduct of his restless and mischievious spirit often fell below par; this in spite of many remorseful promises of reform.

The Westtown School library seems to have been well-stocked; there in February 1856 Cope, at the age of fifteen, read Darwin's *Voyage of a Naturalist* [2] and pronounced it too full of geology. The course of school study, however, was the routine

[2] *Voyage of a Naturalist*, Charles Darwin, Harper Brothers, 1845. 2 vol.

reading, mathematics, Bible study, penmanship, Greek and Latin with a little chemistry thrown in. In the summer the young naturalist made strides ahead in his favorite studies; not being very robust he was sent by his father to work on farms of various relations. These farms differed from year to year; the first was a garden truck farm, the next devoted to wheat and corn and another to fruit raising. By his own account the lad employed his spare time in studying "nurserying, ornithology, herpetology, botany and flageoletology." He explored meadows, woods and fields, collecting birds, snakes, insects, reptiles, fish and flowers, for later comparison in the Philadelphia museum. He became more and more embued with the beauty in Nature, of which he had a strong sense, more and more eager to unravel the plan and meaning of life, both physical and mental, and more and more determined not to become a farmer.

Youth

He was persistent in this latter determination and advanced so many arguments against the economic wastefulness of the contemporary methods of farming that, when he was nineteen, his father finally gave in and set him to studying French and German under a private tutor. Dr. Joseph Thomas, the scholar selected, was an excellent linguist and developed in his pupil a fluency and familiarity with languages which was of great value to him. Cope consented to the language courses with the express understanding that they would "enable me to read useful books of a literary or scientific character."

His first formal contribution to scientific literature came during this same year of 1859 with his communication of a paper on the *Salamandridae* [3] to the Academy of Natural Sciences at Philadelphia, in whose halls he had been an interested student since his sixth year.

The ambitious youth soon convinced his father of the necessity of his studying comparative anatomy at the University of

[3] On the *Primary Divisions of the Salamandridae*, with Descriptions of Two New Species. *Proceedings of the Academy of Natural Sciences of Philadelphia* (Vol. XI), 1859, pp. 122-128.

Philadelphia under Dr. Joseph Leidy as it would give him a proper knowledge of how to treat stock, should the occasion arise. He further remarked that he was already, at the age of twenty, familiar with the main points of anatomical structure and could perfect himself in the minutiae in a winter.

Young Manhood

Having completed the course with Leidy in the early Spring of 1861, he spent some months in cataloguing the reptilian collection of the Academy of Natural Sciences and then proceeded to Washington to study the herpetological collections of the Smithsonian Institution under Professor Spencer F. Baird. The winters of 1861-2 and 1862-3 were passed thus in war-torn Washington, while the summers were spent in farm work and in scientific writing. Most of the papers of these years were on herpetology, but one ventured into ichthyology and one into mammalogy. At the age of twenty-two, in the Spring of 1863, Cope went abroad to study the collections at Berlin, Leyden, Munich, Vienna, Paris and London. He remained abroad a year and returned in 1864 to an appointment as professor of natural science in Haverford College, a post he held for three years and then gave up in favor of scientific exploration and writing.

Manhood

Cope was married in July 1865 by the Quaker ceremony to his distant cousin, Annie Pim. Their only child, Julia, was born in July of the following year. In March 1867 Cope visited Agassiz at Cambridge and examined the great Brazilian collections. Three months later his own life as an explorer of remote and hazardous fields began with the apparently mild proposal of taking his wife and baby to the Virginia Springs for a vacation.

There, in Montgomery County, he explored the cave fauna—a type of investigation in which he was again engaged shortly before his death, thirty years later. In October 1867 he progressed to Maryland, examining the Eocene and Miocene beds which lie between the Potomac and Patuxent rivers. The next

March he turned his attention to the New Jersey marly sands near Pemberton in Burlington County. These he explored with his new found friend, Professor Othniel Charles Marsh of Yale, who was to become one of his bitterest rivals. But in 1868 they explored the marl peaceably together and found three new saurians of apparently known genera, though Cope was not certain of this classification and ascribed them tentatively to *Mosasaurus, Glavialus* and *Brimosaurus*. The summer of 1869 found him among the mountains of McDowell County, North Carolina, hunting insects, salamanders, and fish and investigating the caves of the Black range, Craggy, Blue Ridge and Great Smoky mountains. Later in the season he lived near Raleigh inspecting the Miocene marl which exists thereabouts. In 1871 Cope's private explorations, which had thus far been financed from his own slender allowance, took him to the Kansas Cretaceous, but his field trips thereafter were in part financed by the national or State Geological Surveys with whom he had first become affiliated in 1865.

Work with Geological Surveys

Cope was busy with Herpetology in 1865, when Dr. Worthen of the Illinois State Geological Survey sent him the remains of a carboniferous salamanderlike amphibian for description. He named the creature *Amphibamus grandiceps* and. transferred his enthusiasm for hunting living reptiles into seeking out the fossil forms. Extinct and living forms he considered together and light was shed from one to the other. In 1870 he gave expression to the results of his studies in a well-illustrated *Synopsis of the Extinct Batrachia, Reptilia and Aves of North America,* a brief diagnosis of groups with descriptions of new genera and species from the coal measures of Linton, Ohio. This was supplemented in 1875 by a *Synopsis of the Extinct Batrachia from the Coal Measures,* which appeared as part of the annual report of the Ohio Survey.

In 1872 his friend F. V. Hayden offered him a post with the U. S. Geological Survey and Cope went to Wyoming to examine the Bridger and Bitter Creek regions with a driving activity

which exhausted him and ended in his first serious illness. The trip began like so many of Cope's with three days and three nights in a stage coach, bumping and jerking into the Wyoming wilderness, and consisted in weeks on horseback in an arid land amid constant danger of Indians, who were decidedly upon the warpath, but who fortunately considered Hayden mad and consequently an object of especial divine protection. The following summer Cope worked in the Colorado Miocene, again with Hayden and in 1875 his *Vertebrata of the Cretaceous Formations of the West* was published by the Government Printing Office. Cope's work with Hayden, however, culminated in the publication in 1884 of a volume, popularly known as Cope's Bible: *The Vertebrata of the Tertiary Formations of the West.*[4] Book One of this work comprised the first half of Cope's final report to the Hayden Survey. It includes the Eocene faunas and a part of the Oligocene (Lower Miocene) Rodentia, Insectivora, etc., Carnivora. The second book, to include the Oligocene (Lower Miocene) Ungulata and the Miocene ("Loup Fork") fauna was never published although a large number of the plates prepared under Cope's direction by William Diller Matthew were published in 1915 by the American Museum of Natural History with the co-operation of the U. S. Geological Survey.[5] The failure to get this volume published was one of the great disappointments of Cope's life. When it became apparent that the original Congressional appropriation for the publication would not be available, he spent many weary weeks and months in Washington from 1886 until 1890, trying to get a special item covering the costs passed as part of the Sundry Civil Bill. He waited upon Congressmen, Senators and Secretaries of the Interior, interviewed, prepared briefs, pleaded, and waited. Several times the item was approved by the Senate, but failed in the House. Finally Cope was referred back

[4] Report U. S. Geol. Survey of the Territories, (Hayden), Vol. III, pp. i-xxxv, 1-1009, Pls. I-LXXVa.

[5] Hitherto Unpublished Plates of Tertiary *Mammalia* and Permian *Vertebrata* (With W. D. Matthew). *Amer. Mus. Nat. Hist. Monograph Series No. 2.*

to Major Powell and the volume eventually appeared in the much abridged form of 1915.

Cope served as palaeontologist with the U. S. Geological Survey of the territory west of the 100th Meridian under G. M. Wheeler in 1874 and 1875, working in New Mexico, Montana and Oregon, and eventually publishing his report with that of Wheeler in 1877.[6] The summer of that year [1877] Cope worked with the Wheeler Survey in the Permian of Texas, the results of his investigations being published in several bulletins of the Survey.

Besides his connection with the U. S. Geological Survey, which terminated when Marsh was placed in command, Cope worked with the Indiana State Survey, with the Canadian Geological Survey, and with the Texas State Survey. In the Indiana work he collaborated with Wortman publishing an *Account of the Mammalian Fauna of the Post Pliocene Deposits in the State of Indiana* in 1884 as part of the fourteenth annual report of the State Survey. His studies took him to Canada in the eighties and he became connected with the Canadian Geological Survey with the resultant publication of his *Vertebrata of the Swift Current Creek Region of the Cypress Hills* in that body's annual report of 1885, and of his *Vertebrata from the Tertiary and Cretaceous Rocks of the Northwest Territory* in the Contributions to Canadian Palaeontology, of 1891. The following year he returned to Texas, serving with the State Survey. The chief publication resultant was *A Preliminary Report on the Vertebrate Palaeontology of the Llano Estacado* which appeared in 1893, occupying ninety pages of the fourth annual report of the Survey.

Twenty Years of Intensive Research

The years after his retirement from the faculty of Haverford College were not solely devoted to work for the various Geological Surveys mentioned above. From late autumn until

[6] Report upon the Extinct Vertebrata obtained in New Mexico by Parties of the Expedition of 1874. *Report of the U. S. Geogr. Surveys west of the 100th Meridian (Wheeler) IV. pt.* II. pp. 1-370.

early Spring of these years Cope lived in Philadelphia, studying and describing the fossils collected on summer journeys and those sent him by other collectors in the same fields, writing long monographs and short papers, correcting and revising endless proofs, lecturing before the Franklin Institute and the Academy of Natural Sciences, and after 1878 publishing the *American Naturalist* as well. During these winters he occupied no professorial chair, though in 1873 he was considered by Princeton College for the Chair of Natural History. He was not enthusiastic about this position, however, because it would cut into his hours for research, and President McCosh of Princeton, on the other hand, was unenthusiastic about Cope, or so Cope thought, because of his advanced views regarding evolution. Occasional summers of these twenty years of research were spent away from the collecting fields. During the summer months of 1875 Cope remained in Philadelphia in charge of the division of organic material in the permanent exhibit of the Educational department at the Centennial Exposition; geological and palaeontological specimens of the United States were assembled under his direction and in later years he frequently referred to the Exposition with great pride. In 1878 he went abroad to attend the Dublin meeting of the British Association for the Advancement of Science, to renew his familiarity with the fossil collections at London, Paris and Rheims, and to make the acquaintance of palaeontologists and geologists to whom he was already known through his writings. Among these men in the order of Cope's personal preference were, Professors W. Boyd Dawkins, Leith Adams, Macalister (of Dublin), Traquair (of Edinburgh), and Thomas Huxley—all palaeontologists of the Vertebrata—and among geologists, Professor John Evans, Mr. Hicks of Wales and Mr. Pengelly of Cornwall.

Returning to his field work, Cope visited California and Oregon in 1879 making the friendship of Professor Condon of Oregon, with whom he had long discussions of his present work in the Silver Lake district, of the fossils he had found and discovered in the past, and of those he hoped to find in the

future. 1881 took him back to the Santa Fe trail and New Mexico, this time working alone, while in 1882 he returned to Oregon. During the next three summers his eagerness to increase his funds, for the purchase and collecting of material for his precious monographs, led Cope into disaster. He had inherited more than a quarter of a million dollars after his father's death in 1875 and with almost childlike faith he invested his capital in silver mines in Mexico. He personally investigated the mines and detected silver, but failed to detect the schemes of promoters. Seeing his misplaced trust too late he feverishly threw good money to cover bad. Finally in 1886 he realized that he was in very straightened circumstances; he struggled with poverty for the rest of his life.

Honors came to Cope during his years of intensive research. In 1872 he was made a member of the U. S. National Academy of Sciences and in 1878 of the Societie Geologique de France. The Bigsby gold medal of the Geological Society of London was awarded to him the following year. In 1886 he was elected a member of the Imperial Society of Moscow and received the honorary degree of Doctor of Philosophy from the University of Heidelberg. This was his only academic degree. In 1891 the results of his research were recognized by the award of the Hayden Memorial medal. Distinction had also come to him through his connection with the Academy of Natural Sciences, the American Philosophical Society and the *American Naturalist*, of which he was editor and publisher.

Connection with the Academy of Natural Sciences and the American Philosophical Society

Cope's connection with the Academy of Natural Sciences at Philadelphia began with his first visit to its halls, when he was six years old. The publication of his first paper in the Academy Proceedings of 1859 strengthened the bond his constant childhood visits had made and upon coming of age in 1861 he became a member of the Academy, whose herpetological collections had already afforded him his first scientific job. For twenty years thereafter Cope's shorter papers, with the exception of

those appearing in the *American Naturalist,* were usually published by the Academy.

He served it as Curator from 1865 until 1873, as Corresponding Secretary from 1863 until 1876 and as a member of the Council in 1879, but he was not satisfied with it and his outspoken criticism of the management of its affairs, which he believed placed buildings before publications and wealth before accomplishment, made him many enemies. He suggested three fundamental changes in its organization without avail: first that a series of fellowships open only to experts of established reputation be inaugurated; second, that the officers of the Academy should be selected from the fellows only; third, that the Professors should be, *ex officio,* members of the Council. This attempt to keep science for the scientists, as far as the actual machinery was concerned, was frowned upon and defeated.

Finally in 1883 Cope resigned from the Academy and in 1885 described himself as elected to "a position of honor if not emolument in the American Philosophical Society." For years those papers not published by the U. S. Geological Survey, the *American Naturalist* and the *Open Court* or the National Academy of Sciences were included in the proceedings of the American Philosophical Society. Yet in making his will Cope forgot the Philosophical Society and remembered the Academy.

Editor of the American Naturalist

The American Naturalist of Salem, Massachusetts, was for sale in 1878; Cope bought a part interest. He moved the magazine to Philadelphia and arranged to edit it jointly with Professor A. S. Packard. In 1887 he became editor-in-chief and so continued until his death, but although it provided him with an organ for disseminating his opinions on science, sociology, religion and government and thus increased his prestige and influence, the *Naturalist* was a constant drain upon his purse and upon his energy, as its publishers were numerous, difficult to manage and expensive.

Cope's two most important contributions to the literature of Evolution were issued independently of the *Naturalist,* the

Origin of the Fittest being brought out by Appleton in 1886 and *Primary Factors of Organic Evolution* by the Open Court Publishing Company in 1896.

Later Years

It being apparent in 1886 that Cope had been swindled out of his patrimony and that something must be done to meet even the modest expenses of his family, he leased his Philadelphia dwelling and moved into the adjoining house which he had previously used as a workroom and storehouse. He merely pitched camp among the bones and manuscripts and set up house-keeping. He began negotiations for the sale of his North American fossil collection and endeavored to secure an appointment as Assistant Secretary of the Smithsonian Institution, but failed. He was, therefore, doubly glad to receive the professorship of geology and mineralogy at the University of Pennsylvania in 1889 and to occupy that position until 1895, when he was transferred to the professorship of zoology and comparative anatomy previously held by Dr. Joseph Leidy.

He went joyously to his work with the Texas Survey in 1892 and 1893, investigating both that state and North Dakota. These were his last Western trips; the remaining three summers of his life were varied only by short trips to eastern caves, such as the Port Kennedy caves in Pennsylvania and the Megalonyx caves in Ohio and Kentucky. The sale of his North American fossil mammalian collection was concluded in 1895 to the American Museum of Natural History, which also later secured the Pampean collection he had bought from Buenos Ayrian scientists in Paris in 1878. Cope hated to part with his North American mammalian more than any other feature of his poverty, but he remained gay and cheerful despite his disappointment and despite the fact that he was beginning to be threateningly ill. In 1896 he was elected to the presidency of the American Association for the Advancement of Science and would have delivered the presidential address in August 1897 had his long-menaced health held out. He fell ill in the spring of 1897 and continued doggedly to attend his classes at the

University, but in April he became really very ill and on the twelfth of that month he died. Shortly before his death he delivered in delirium a brilliant and unified lecture on the *Felidae* and his last conscious sight was of giant bones, piled on every side of his cot. The Quakers, from whose Society Cope had resigned in 1878, came to bury him and to help execute his will, dated October 1, 1895, the principal provisions of which were as follows:

I hereby appoint Jno. B. Garrett of Philadelphia and Henry F. Osborn of New York to be the Executors of this Will. In case of the death of either party, I appoint as substitutes Asa S. Wing of Philadelphia and William B. Scott of Princeton, N. J., the former in place of J. B. Garrett, and the latter in place of H. F. Osborn.

. . . Of my scientific books I direct that all which they desire shall be taken by the Biological School of the University of Pennsylvania for their library, and the remainder shall be sold and the proceeds divided equally between my wife and daughter.

Of my collections, I direct that all those preserved as wet preparations shall be given to the Academy of Natural Sciences for their museum.

I leave my osteological collections to the School of Biology of the University of Pennsylvania for the use of original investigators primarily, and for use by students when said specimens are not in use by original investigators.

My collection of minerals I present to the University of Pennsylvania to be placed in their general collection. My collection of skins of animals together with the skeleton which accompanies each skin, if any there be, I present to the Academy of Natural Sciences of Philadelphia.

My collection of Fresh water Mollusca I present to the School of Biology of the University of Pennsylvania; the first set of duplicates to go to the Cincinnati Society of Natural History, and the second to the American Museum of Natural History of New York.

My palaeontological collections I divide into three parts. *First,* the North American Collection; *Second,* the South American, i. e., the Pampean Collection which I purchased of the Buenos Ayrian Exhibitors at the Paris Exposition of 1878, and small collections from the West Indies and Mexico; *Third,* European Collections, chiefly from the Miocene of Allier, France. I direct all these to be sold for the benefit of my estate. I advise my executors that these collections have cost me about $50,000.00. I place no restrictions on them as to the manner of sale except that it may be done as soon as the best advantage indicates.

Of the proceeds of all sales hitherto mentioned in this will, I direct

that my debts shall be paid. . . . The remainder, which I suppose will amount to about $40,000, I leave to the Academy of Natural Sciences of Philadelphia as an endowment for a professorship or curatorship of Vertebrate palaeontology under the following conditions: Said professor shall be an original investigator of merit who shall be elected by the Council of the Academy and shall have the approval of the U. S. National Academy of Sciences, as an original investigator of merit. His position and services shall be those of a professor as defined in the present by-laws of the Academy: i. e., he shall have entire charge of the material embraced in his department, and the curators shall not interfere with his jurisdiction excepting to see that he does not neglect his duties. Of the income of this sum, $400 per annum shall be used for the procurement of vertebrate fossils either by collection or by purchase.

The remainder of my real and personal estate I leave to my wife during her lifetime; and after her death to my daughter, Mrs. Julia C. Collins. In case both die, I leave said remainder, one half to my son-in-law, W. C. Collins, and the other half to augment the purchase fund of the chair of vertebrate palaeontology in the Academy of Natural Sciences.

Codicil. March 24th, 1896.

I direct that after my funeral my body shall be presented to the Anthropometric Society and that an autopsy shall be performed on it. My brain shall be preserved in their collection of brains, and my skeleton shall be prepared and preserved in their collections, in a locked case or drawer, and shall not be placed on exhibition, but shall be open to the inspection of students of anthropology. The remainder of my body, I direct, shall be burned and my ashes be preserved in the same place as shall contain the ashes of my esteemed friends, Dr. Jos. Leidy and Dr. Jno. A. Ryder.

Contributions to Geology and Stratigraphy

Inextricably involved in Cope's chosen task of unravelling the problems of life, the structure, functions, development and phylogenetic descent of animals, as well as the broad metaphysical questions which underlie and condition all these problems, were his investigations of geology. These were in his eyes subordinate to palaeontology, but necessary to its proper chronology, consequently he had very little to say concerning structural or dynamic problems of geology and regarded every question in that field from the strictly historical view. Stratigraphy, the determination of limits, distribution, succession and

geological date of the formations in which his fossils were embedded, as well as the correlation of these formations with their equivalents in other parts of the world, constituted his geological occupations; for he could make out the phylogenies of the various animal groups only after he had determined the true chronological order of succession of the genera composing the phyletic series.

When Cope began his studies in the Cretaceous of Kansas in 1871, the whole region was comparatively new and for the most part geologically unexplored; he was, therefore, forced to work out the stratigraphical succession for himself. This was most fortunate, since it made him personally familiar with the strata in which the fossils lay, a rare opportunity for scientists of that day, among them, Leidy, who had worked all his life from bones picked up by chance passersby from the surface of the ground where they had been weathered out of the matrix. Sternberg's method of getting out skeletons and shipping them so far as possible *in situ* had not yet been perfected, so Cope came to geology through palaeontology. Accordingly most of his writings on the subject are scattered through his palaeontological papers and would be very difficult to reassemble, but in the opinion of Professor William Berryman Scott, from whose material this article is prepared, those scattered observations of Cope's were epoch making.

They came, says Professor Scott, at a time when "the haziest ideas were entertained regarding the position and succession of most of the numerous and extensive fresh-water formations, which characterize the western part of the country. It would be an exaggerated claim to say that he had brought order out of the chaos, but it is hardly too much to say that he, more than any other single individual, contributed to this great result. Such was his power of insight that he was occasionally too far ahead of his contemporaries, and only of late have certain of his views received their just meed of appreciation. In some instances, indeed, we are coming back to the opinions which he first promulgated, but which were ignored or rejected at the time.

"Great as his genius undoubtedly was, Cope was not, even as an investigator perfect and free from every fault; to use a Gallicism, he had 'the defects of his qualities.' He was so impressed with the immensity of the work to be done, with the necessity of speed, and with the shortness of the time allotted to him, and he was often so carried away by the rushing impetuosity of his thought, that he published no little hasty and ill-considered work. He frequently made blunders that a little more care and consideration would have enabled him to avoid, so eager was he to say what he had to say, and then pass on to the attack of some new problem. To balance this defect, however, he had no tendency to pose as infallible, or to defend errors simply because he had himself committed them. While extremely clear as to his own opinions and the grounds upon which he held them, and while ready to give and take hard knocks in the defense of his views, he was always ready, on good reason being shown, to change those views, and he allowed no weak regard for fancied consistency to hamper the freedom of his thought. . . . Those who are familiar with the vast and desolate regions where the work was done, and who know the great difficulties which the pioneer explorer has to overcome, will view the matter in a very different light and will always regard with admiration the rapidity, clear-sightedness, and skill with which the great complex of fresh-water deposits was marshaled in orderly array, their succession determined, and their equivalences with similar deposits in other parts of the world made out."

This correlation of the various fossiliferous horizons of North America with those of Europe, made possible by Cope's wide and accurate knowledge of the successive vertebrate fauna of both continents, was one of his most valuable contributions to geology. Of this Professor Scott wrote in 1897:

"Of late it has become rather the fashion to deprecate as premature all attempts at correlating American and European formations and even to deny the possibility of making such correlations in any trustworthy way. From the strictly geological point of view, such a conservative attitude is natural

enough; but Cope did not regard the question from a purely geological standpoint. He was, above all things, a zoologist, and his principal life work lay in tracing the origins, phylogenies, and relationships of animals, their migrations and geographical distribution, and he clearly saw that such determinations could not be successfully undertaken unless the order of successive appearance of the various animal types in the different continents could first be established. To this end, geological correlations of widely separated deposits are an indispensable necessity, and a false correlation is better as a working hypothesis than none at all, for it sets up a definite thesis in place of vague surmises.

"In several of these determinations of the equivalences between the fresh-water Tertiaries of North America and those of other continents, Cope was a pioneer, and while not all of his correlations have stood the test of fuller knowledge, many of them have only grown stronger with the advance of time and stand out as guide-posts in the further prosecution of the work. For example, his correlations of the Wasatch with the Suessonian of France (in which he followed Marsh), and of the White River with the Oligocene of Ronzon, have been abundantly confirmed by discoveries undreamed of when the equivalences were first suggested. The value of these determinations to the morphological palaeontologist can hardly be overestimated, and every investigator owes a debt of gratitude to Cope for his labors in this department of geology."

A cursory survey of Cope's work in geology, taken in the order of geological chronology, begins with his single interest in the Permian rocks among the Palaeozoic formations. A controversy about the existence of Permian rocks in the United States had been going on since 1852, when Marcou had reported their presence in Texas and Swallow, Meek and Hayden had confirmed this discovery by finding them in Kansas as well, in 1858. Other authorities disputed this determination and maintained that there was no well-defined Permian rocks in the United States. In 1877 Cope obtained his first specimens of Amphibia and Reptilia from Texas and proceeded to publish a

series of descriptions of extinct vertebrata from the Permian and Triassic Formations of the United States, in which he fully determined the Permian character of rocks in both Texas and Illinois. The researches of I. C. White and Fontaine upon the plants and of C. A. White upon the invertebrates later confirmed Cope's conclusions.

This identification of horizons in regions where they had not previously been known continued in Cope's work in the Triassic, Jurassic and older Cretaceous. Though he neither discovered new formations, nor corrected the reference of those mistakenly placed in the geological columns, he did investigate very thoroughly, especially in the Cretaceous. He was the first to discover Dinosaurian remains in the Laramie stage, and is said to have been the first to recommend the reference of that horizon to the Cretaceous, a radical innovation which was finally adopted by his contemporaries, as it proved its value in giving a fixed point in the obscure formations intervening between the Cretaceous and Tertiary.

In the unravelling of the fresh-water Tertiaries which cover such vast areas of the West lay Cope's most signal service to geology. It is difficult to exaggerate the value of these services according to Professor Scott, who has summed them up, as follows:

"First of all should be mentioned his discovery and identification of the Puerco, or oldest Eocene, which may fairly be called 'epoch-making.' Not only was a very extensive, entirely new and highly significant fauna brought to light, but also the existence of a long time-interval between the Laramie and the Wasatch was demonstrated, showing that the supposed continuity of sedimentation connecting those horizons was illusory. This discovery necessitated an entire change in the views concerning the geological history of the Western region in post-Cretaceous times. The Puerco carried the Eocene much farther back than had been expected, and opened up a new world to the palaeontologist.

"The succeeding Wasatch formation had been discovered and named by Hayden, and its correlation with the Suessonian

of Europe had been pointed out by Marsh, but it is to Cope that we owe much the greater part of our knowledge concerning its distribution, its relations, and its place in the geological column. Personally, or through his collectors, he thoroughly explored the Wasatch of New Mexico and Wyoming, elucidating its fauna with wonderful skill and insight, and strengthening the theory of its close correspondence to the Suessonian of France, with which his studies in that country had made him familiar.

"In the Bridger formation, Cope added very largely to what was known regarding the vertebrate fauna, and established the position of the Wind River beds as forming a substage at the base of the Bridger and making a transition from the older Wasatch to the Bridger proper. He also made a classical series of investigations upon the fishes of the Green River shales, and pointed out the probable equivalence in time of these beds with those of the Wind River substage. He first described the fauna of the Manti beds of Utah of approximately contemporaneous age."

Hayden and Leidy had very thoroughly examined the White River formation and its very rich vertebrate fauna, and Leidy in his famous monographs had determined these beds as being of Miocene age. Cope challenged this determination and referred the formations rather to Oligocene, stressing the importance of their correspondence with European formations, but the followers of Leidy remained firm adherents of the Miocene determination and considerable confusion resulted. The misleading Miocene determination remained in use for some time, despite Cope's detection of White River beds in North Dakota two hundred miles north of the first discovery and his extension of the range of that formation into the Swift Current region of the Northwestern territory of Canada. Fossils sent him by the Canadian Survey facilitated this latter determination and showed him certain resemblances to the contemporary life of Europe in addition to those which he had detected in the United States.

The Amyzon shales of Nevada and central Oregon and the

Florissant beds of Colorado came under Cope's examination during his preparation of a description of a series of fishes which had been obtained from these formations. He was inclined to consider them of Oligocene or late Eocene age, although somewhat in doubt as to their exact geological date, because of the absence of decisive stratigraphical indication and because fossils common to them and other localities were lacking. In dealing voluminously with the abundant vertebrate fauna of the John Day stage, Cope had little to say regarding its geology beyond that which had been said by his predecessors. In the Loup Fork, however, his observations were original and contrary to precedent.

Leidy had first described the Loup Fork fauna from fossils sent him by explorers and fur traders, who had picked up bones lying on the surface of the ground. These had been weathered out from overlying Pleistocene deposits and were intermixed with too many extinct and peculiar genera to altogether retain their modern classification. Leidy accordingly determined this admixture of fauna as Pliocene, but Cope was suspicious of this reference from the first. When his opportunity of personally examining the Loup Fork beds presented itself, he sought out areas where the strata were at the surface and where no newer overlying formations could falsify his collections. He thus accurately determined the actual elements of the Loup Fork fauna and found them lacking the Pleistocene forms which former casual collections had mistakenly included in them. He came at once to the belief that the Loup Fork beds were not Pliocene at all, but Upper Miocene and extended their area to New Mexico, Texas and the valley of old Mexico. Though considered a great reform in Western stratigraphy by many American geologists this determination was not universally adopted, and while some authorities continued to uphold Leidy's reference confusion prevailed, much to the embarrassment of European writers.

Having determined the fauna as Upper Miocene, Cope proceeded to show that the formation is divisible into two distinct substages. Grinnel and Dana had discovered certain lacustrine

deposits in the valley of the Smith River in central Montana in 1875 and determined them as Pliocene, by which they supposedly meant Loup Fork. Cope sent a collector into this region and from the material gathered showed that these beds which Cope assigned to Nebraska and South Dakota as well as Montana, constituted a substage of the Loup Fork and were older than any part of that formation which had been known up to that time. This determination was of significance in helping to bridge the gap between the John Day and the typical Loup Fork and eventually proved to be of great value in making correlations with the fresh-water deposits of the European Upper Miocene.

The Pliocene of the interior portion of the United States was at this time very vaguely known, but during his studies of the fishes Cope identified certain beds in Idaho and Central Oregon as Pliocene and proposed the name Idaho beds for them. He also was the first to make known the Blanco beds of Texas, describing their stratigraphy, geographical distribution and fossil contents, and thus disclosed one of the most typical and unmistakable of North American fresh-water Pliocenes.

In the Pleistocene, Cope's work consisted in the determination of the successive mammalian faunas and the consequent foundation of the divisions of the North American Pleistocene. This work was thoroughly done in the Sheridan or Equus beds of the West and Southwest in widely separated localities, and in the caverns of the East. Notable among these caverns were his early and later investigations of the extensive assemblage of Pleistocene vertebrates in the Port Kennedy bone cave of Pennsylvania, which formed the subject of one of his last publications. The Sheridan beds and the Megalonyx beds of the East, he at first considered Pliocene, but eventually changed his opinion and classed them with the Port Kennedy faunas as Pleistocene.

Investigations of the geology and palaeontology of the Atlantic coast, though they formed Cope's first introduction to palaeontology, yielded up such fragmentary and unsatisfactory

material that the results of his labors are less apparent and he remains the geologist, palaeontologist and evolutionist of the Western plains.

Contributions to Herpetology[7]

Cope was a naturalist, not a specialist in one branch of natural history. Herpetology, however, was the first field to interest him and remained one of his chief studies, so that his work in this line ranks with the specialization of many men. The first exhibit of the Museum of the Academy of Natural Sciences at Philadelphia of which the six-year-old boy wrote to his grandmother was the mammal *Hydrarchus* (Zeuglodon) then falsely labelled the whale-like lizard. Visiting the Museum a year or so later, he noted in his little journal: "Some saurians which are fossil skeletons that are found in the rocks of England, but it is very curious that they are monstrous sea lizards." In the woods and fields at Fairfield, in the school grounds at Westtown and during summers on the Pennsylvania farms of various cousins, he sought salamanders, snakes and tortoises under roots, stones, fallen trees and layers of leaves and identified his trophies with those described in his father's library or preserved in the Academy Museum.

Just before his fifteenth birthday he wrote to his father, "I caught a large water snake or water wampum, as they are called here—one of the Colubers—in Brandywine and brought it home. It was about as long as my leg, but very thick for its length, . . . I afterwards found it had eaten a large bull frog . . . I soon convinced myself it was not (poisonous) by examining its mouth which wanted fangs, and as all non-venomous have, it had four rows of teeth in its upper, and two in its lower jaw, and two rows of scales under its tail." Throughout his life he collected snakes, toads and salamanders whenever he found a strange species, shipping them home, some

[7] See Theodore Gill, Retiring Presidential Address before the American Association for the Advancement of Science, 1897; also *Proceedings of the American Philosophical Society,* November 12, 1897.

alive and some in alcohol, from the muddy streets of San Antonio, the deserts of New Mexico and the mountains of Nevada and North Carolina. When Cope was nineteen, in 1859, his first formal contribution to scientific literature appeared in the April Proceedings of the Academy of Natural Sciences under title, *On the Primary Divisions of the Salamandridae, with descriptions of Two New Species.* Therein the youthful scientist instituted modifications of the systems previously adopted in the United States.

While still too young to become a member of the Academy, which he joined in 1861 upon coming of age, he occupied several winter months in cataloguing the serpents contained in its Museum and introduced innovations in the systems of classification then in use. He next studied the herpetological collections of the Smithsonian Institution under Spencer F. Baird and then went abroad for his intensive study of the collections of England, France, Austria, Holland and Prussia. His studies covered besides specific details and general taxonomy, the consideration of anatomical details of the reptiles and amphibians, the modifications of general organs, geographical distribution, genetic relations and physiological consequences. For five years his publications were devoted almost exclusively to the reptiles and amphibians and through this channel he entered palaeontology, writing in 1865 his first paper in this field, a description of the stegosaurian amphibian called *Amphibamus grandiceps,* and though the scope of his writings widened thereafter to palaeontology, geology, philosophy and even sociology, he never lost sight of his interest in herpetology nor ceased contributing to it.

Theodore Gill has said of Cope: *"He found Herpetology an art; he left it a science; he found it a device mainly for the naming of specimens; he left it the expression of the co-ordination of all structural features."* Cope approached herpetological classification boldly and critically surveyed the work of the authorities of the day, Duméril, Bibron and Günther. Where he saw that changes were needed he calmly proposed that they be

made and backed up his suggestions with such sound reasoning that they were adopted.

The anurous amphibians and the saurian reptiles were differentiated in groups, at the time Cope's work began, chiefly on account of superficial characteristics: such as the mode of fixation of the tongue, or its lack; the development of the toes to disklike expansions at the tips, or to simple attenuation; and the presence or absence of teeth. Cope proceeded to investigate the group anatomically and reached new conclusions. He found that important differences existed in the structure of the sternum, especially in the connection of the lateral halves; that in the common tree-toads of Europe and North America the so-called clavicle and coracoid of each side are "connected by a longitudinal arched cartilage which overlaps that of the opposite side" while in the common frogs the clavicles and coracoids of both sides are connected by a single median cartilage. He named the former of these groups, the toads, Arcifers and the latter, frogs, et cetera, Firmisternials and placed the Firmisternials higher in the evolution scale because of their more highly developed shoulder girdle. The development of teeth he first regarded, with his contemporaries, as a very important factor of classification, but later came to subordinate.

Applying his principle of a skeletal basis of classification, Cope dissected the lizards and redistributed them into new divisions, based upon an equation of all skeletal characteristics: such as, structure of the cranium, concordance and variations in the development of bones, structure of the vertebrae, shoulder girdle, teeth, tongue and pholidosis; rather than the previous superficial grouping by tongue form, arrangement of scales, and development of legs and feet. This new method of classification became a matter of bitter correspondence between Cope and the old school herpetologists, but finally won recognition through the sanction of the British Museum catalogues. It crystalized into two volumes which remain, though out-dated, the only comprehensive works on American Herpetology: *The Batrachia of North America,* published in 1889,

and the post-mortem complementary volume, *The Crocodilians, Lizards and Snakes of North America.*

Contributions to Ichthyology [8]

Cope's contributions to the classification and evolution of the fishes proved to be of such great importance that many of the orders and suborders recognized by him have been adopted by subsequent ichthyologists, especially in America. Beginning with the fresh-water fishes of the Carp family in 1861, he published a series of papers from 1864-1891, including *Partial Catalogue of the Cold-blooded Vertebrata of Michigan; Synopsis of the Cyprinidae of Pennsylvania* and *Observations of the Systematic Relations of the Fishes.* Some of the most interesting genera of North American fresh-water fishes were first made known by him (1864-1869). He attempted to arrange them in natural groups and was the first to appreciate the importance of certain characters, such as the structure of the dorsal fin and the relation of the air-bladder to the digestive tract.

His next great series of contributions (1871-1891) dealt with the natural subdivisions of the entire series of fish-like vertebrates. In these papers the following subjects of major interest were dealt with:

(1) The division of the fishes into classes and subclasses.

(2) The analysis and reclassification of the old and unnatural group of "ganoids."

(3) The division of the higher teleosts, or Actinopteri, into no less than twenty-four orders, eight of which survive today.

(4) The grouping of a series of fresh-water families, including the suckers, carps, loaches, characins, etc., into the order Plectospondyli.

(5) The breaking up of the old unnatural assemblage of eel-like fishes into several orders and many families.

(6) The analysis and classification of the Devonian fossil

[8] Notes by William King Gregory. For a detailed appreciation, see Gill, Addresses in Memory of Edward Drinker Cope . . . *American Philosophical Society,* November 12, 1897.

fishes generally called crossopterygians into a series of orders and suborders.

Cope's contributions to the fresh-water fishes, like his observations on the snakes and lizards, were based at all points on personal observation of the material and an adventurous spirit in the discovery of new and hitherto neglected anatomical characters of possible value as criteria of classification. His studies on the classification and phylogeny of fishes as a whole were based partly upon a large collection of skeletons of fishes from all parts of the world, which he had purchased from Professor Joseph Hyrtl of Vienna.

Cope's influence in the subsequent development of ichthyology was far greater than would appear on the surface because many of his orders and suborders were adopted with slight modifications in the classification of the fossil fishes in the British Museum by Dr. Arthur Smith Woodward.

Contributions to Mammalogy

Cope's most numerous and voluminous writings were devoted to mammals, and to appreciate the importance of his contributions in this group it is necessary to cast a brief glance over the history of mammalian palaeontology. Cuvier, the founder of this branch of science, had represented the *école des faits* in opposition to Geoffrey St. Hilaire, and founded a school wholly opposed to generalization as to the origin and succession of animal life, and firmly adherent to the Special Creation hypothesis. As a master of comparative anatomy, Cuvier exerted an immense influence upon the succeeding French palaeontologists, such as Jourdan, Croizet, Christol, De Blainville, Aymard, Lartet and Pomel. It is true that De Blainville and Gervais showed a wide range of knowledge but Gaudry was the first of the French palaeontologists to grasp the spirit of evolution. In Germany, Jager and Blumenbach ranked as more or less voluminous descriptive writers, while Kaup showed superior powers of analysis.

Cuvier's unnatural classification of the hoofed animals into the *Solipedes,* or horses, and *Pachyderms,* or rhinoceroses and

hippopotami, prevailed and was adopted even by Leidy in this country. Richard Owen, by far the greatest anatomist after Cuvier, made a decided advance, and, as in the classification of the fishes and reptiles, was the direct predecessor of Cope. Partly anticipated by De Blainville, he defined the new mammalian orders, *Marsupialia* and *Toxodontia,* and especially broke down Cuvier's classification of the Ungulates by distinguishing the *Perissodactyla* from the *Artiodactyla* upon the basis of foot structure, the importance of which Cuvier himself had only dimly perceived.

In this country the earlier contributions of Jefferson, Harlan and Gibbes were over-shadowed in the mid-century by the numerous valuable works of Leidy, who became at once the founder of American vertebrate palaeontology, although in deference to the theologic spirit of the times he held in check the philosophical spirit both in anatomy and evolution. Thus, from all this long post-Cuvierian period and immense number of facts, there issued only two generalizations, the first of which may be regarded as the great laws or principles in the evolution and classification of the mammalia. These laws are as follows:

I. *The Law of Brain-Growth*—This principle, that the older mammalia had smaller brains, and that in order of succession there was a steady increase in brain size, was enunciated by Lartet, and has been subsequently elaborated and demonstrated by Marsh.

II. *The Classification of the Hoofed Animals by Foot-Structure*—This was discovered by Owen in his division above alluded to, which first directed attention to the importance of differences in the feet.

The three vertebrate palaeontologists of the new period who responded most fully to the Darwinian movements were Huxley, Marsh and Cope. Huxley unwillingly entered the field, but soon found an opportunity of overthrowing Cuvier's Law of Correlation. His greatest generalization was the central position of the order *Insectivora.* He had, however, few opportunities of working upon fossil mammals; he erroneously placed *Paloplotherium* instead of *Hyracotherium* in the ancestral horse

line, and erroneously supported Reichert's theory of the homology of the quadrate bones. Cope and Marsh alike responded to the Darwinian impulse but along entirely different lines. In Russia appeared Waldemar Kowalevsky, who had a short but brilliant career in mammalian palaeontology. He announced the third great principle:

III. *Law of Adaptation of Foot Structure in Ungulates by Reduction, Accompanied by Shifting of the Metapodials*—Kowalevsky's ancestral type of ungulate or protungulate, like that of Huxley, was believed to possess five digits.

In the meantime the gifted John A. Ryder, of Philadelphia, was attacking the problems of the mechanical evolution of the feet and teeth from the Lamarckian standpoint.

Cope, who had practically entered mammalian palaeontology in 1870, found a great field of facts lying fallow before him, with the three principles outlined above as means of interpretation. Keen to wed philosophy with anatomy, in 1873 he added to the generalizations of Huxley and Kowalevsky the additional principle:

IV. *The Ancestors of the Hoofed Animals Possessed Bunodont, or hillock-like Teeth*—This prophecy was speedily verified by Wortman's discovery of *Phenacodus*. This discovery led Cope on to a reclassification of the entire group of ungulates by foot-structure—the logical outcome of the movement in which Owen, Huxley, Ryder and himself had participated. This classification centered about the following principle:

V. *The Law of Taxeopody: that the Primitive Feet of Hoofed Animals were Serially Plantigrade, Like those of the Bear, with Serial Unbroken Joints*—Thus he proposed in the early eighties the four new orders, two of which have been permanently adopted into palaeontology: Equivalent to these are three orders proposed by Marsh:

Cope	Marsh
Taxeopoda, 1882	*Protungulata,* 1884
Amblypoda, 1875	*Amblydactyla,* 1884
Condylarthra, 1881	*Clinodactyla,* 1884
Diplarthra, 1883	

Kowalevsky, in 1873, had pointed out the significant articulations of the metapodials in the *Artiodactyla;* Cope here showed the still greater importance of the mutual articulations of the podials, firmly establishing thereupon the orders *Condylarthra* and *Amblypoda,* uniting Owen's Perissodactyla and Artiodactyla into the *Diplarthra,* and by hypothetical phyla connecting the Proboscidea and Hyracoidea with a still-to-be-discovered plantigrade, bunodont stem, the "protungulate" of Huxley, Kowalevsky and Marsh. These generalizations despite errors of detail and interpretation which Rutimeyer and Osborn have pointed out, constituted the first distinct advance in mammalian classification since Owen demolished Cuvier's "pachydermata"; they rank with Huxley's best work among similar problems, and afford a basis for the phylogenetic arrangement of the hoofed orders which has been adopted by all American and foreign palaeontologists.

Having thus raised the foot and head, regions of the body so long neglected by the followers of Cuvier (with the exceptions noted), to a position of prime importance in classification, it was his good fortune to discover in the collections from the Puerco or basal Eocene the following law:

VI. *Law of Trituberculy: that all Types of Molar Teeth in Mammals Originate in Modifications of the Tritubercular Form*—It became apparent to him that the hoofed mammals had sprung from clawed ancestors, but the Wasatch period was too remote from the parting of the ways to furnish conclusive evidence. This evidence came in a flood from the underlying Puerco fauna, the systematic evidence of which constitutes the most unique section of Cope's work among the extinct mammalia. From this material originated the above great generalization—namely, that the primitive pattern of the molar tooth consists of three great tubercles, a generalization modified and extended by Osborn, Gregory and others. Around this *trituberculy* center the whole modern morphology of the teeth of the mammalia and the establishment of a series of homologies in the teeth of most diverse types, applying even in the teeth of man. The force and application of the trituber-

cular law Cope clearly perceived, but left to others fully to work out and demonstrate. It promises ultimately to give us the key to the entire phylogeny of the mammalia, extending to every division of the marsupialia and placentalia.

Thus the final philosophical working basis for the evolution of the hoofed, as well as the clawed, animals has been well established, for, as Professor Marsh observes in his monograph on Dinocerata, "the characters of the most importance in the evolution of the Ungulates are the teeth, the brain, and the feet."

It now only remained for Cope to take another step beyond Huxley and Kowalevsky and, aided by fortunate discoveries in the field, he demonstrated that the ancestors of the hoofed animals were clawed animals, establishing the seventh law:

VII. *The Hoofed Orders Arise from the Clawed Types of Creodonta and Insectivora.*

So much for the great generalizations which establish Cope's historical position in mammalian palaeontology. These are the mountain peaks, the points where explorations and discovery were followed by happy inspiration, in a chain of contributions which includes his exposition of the faunal succession of the mammals from the base to the summit of the Tertiary, as well as two or three discoveries of great interest in the Cretaceous. His most conspicuous work relates to the Puerco, with its extremely primitive hoofed and clawed animals and primates. Here he established the existence in this country of the *Plagiaulacidae* and defined the order *Multituberculata*. That from the Wasatch is perhaps next in value, and in succession rank his contributions from the John Day, Loup Fork, Blanco, Palo Duro, and Port Kennedy Bone Cave.

Cope as a Field Explorer

As an explorer he had marked success, finding the unique skeleton of *Hyrachyus*, of *Loxolophodon*, a name which was telegraphed to the American Philosophical Society, and converted by the operator into *Lefalophodon*. He also found the last of the great race of Uintatheres at the top of Washakie

Mountain of central Wyoming. In the Bridger, Cope himself found the lower jaw of *Anaptomorphus,* a little monkey with a dental formula like that of man, which, owing to its extreme antiquity, occasioned him a greater surprise than any discovery he ever made. We owe to him alone our knowledge of the scanty Wind River fauna. From the White River Oligocene his materials were poor and his work less satisfactory. From the rich Upper Oligocene, with the assistance of Wortman, he secured fine collections and has especially enriched our knowledge of the *Anchitheriidae, Felidae* and *Canidae.* From the Upper Miocene, Deep River and Loup Fork beds he has practically originated all that we know, especially of the rhinoceroses, horses, mastodons, camels, and other ruminants and carnivora. Of the latter fauna his most complete papers were upon the evolution of the *Oreodontidae.* His latest contributions to our knowledge of the fossil mammalia were upon the fauna of the Blanco and Palo Duro, or Goodnight beds of Texas, and the rich cave fauna from Port Kennedy, Pennsylvania, brought together by his warm friend, Dr. H. C. Mercer.

The *Tertiary Vertebrata,* Vol. III, of the Hayden quartos, published in 1884, is his most inspiring contribution to palaeontology, including his studies of all the vertebrate fauna of the Tertiary Lakes west of the Rockies. This work of over a thousand pages and seventy-five plates is said to have been the despair of the Public Printer, owing to the constant additions made while in press. It extends from the Puerco to a portion of the lower Miocene fauna. Besides the full description and illustration of the great hoofed orders above alluded to, it contains the full exposition of the characteristic forms of *Creodonta,* an order of primitive Carnivora, which, as we have seen, he separated from the Marsupialia in 1875, and in which he placed six families of mammals from different parts of the world. It will be observed that this volume is entitled "Part I." Cope had in mind a second part which would hardly have been less voluminous. The plates for this part were all prepared and in themselves constituted such an important feature in American palaeontology that at the urgent instance of the present

author, they were finally assembled and ably edited with explanatory legends by Dr. William Diller Matthew. They were published by the American Museum of Natural History in 1916. the volumes being distributed with the cooperation of the U. S. Geological Survey.

Before leaving the mammals it is fitting to speak of his Lamarckian work upon "kinetogenesis," or the mechanical origin of the hard parts of the body, especially the teeth, vertebrae, and limbs. An invaluable paper by his friend and later colleague, Ryder, put him upon this line of investigation, the results of which he published in a long series of papers, culminating in his memoir upon the "Origin of the Hard Parts of the Mammalia" and in his collection of essays upon the "Origin of the Fittest" and "Primary Factors of Organic Evolution." One of his chief motives in these researches was the demonstration, which he believed they afforded, of the hereditary transmission of the effects of individual efforts, use and disuse. Even if this Lamarckian motive is subsequently shown to be an illusive one by our future knowledge of the real nature of evolution, these investigations lose little, if any, of their intrinsic value. First, as in all his work, he brings together an immense array of valuable facts and observations; second, he extends the principle of the independent origin of similar structures; third, he in most cases successfully establishes the actual mechanically adaptive or teleological relations of the parts described; fourth, he traces the course of phylogenic modification in a number of important organs and thus establishes certain obscure homologies, notably those in the teeth of *Amblypoda, Coryphodon* and *Uintatherium*.

Contributions to Ornithology

Cope was an occasional contributor to the literature of ornithology. He was the first to recognize *Laelaps aquilungus* as the probable link between birds and reptiles. He continued to contribute short descriptions of birds from time to time but never became more than an intelligent and well-informed amateur in ornithology. However, a school essay written at

the age of seventeen gives strong indication of an accurate knowledge of the habits of birds and shows that Cope might have developed into a popular bird-man if he had not happened to concentrate his forces in other fields of natural history. In that essay the youth said in part, regarding the Yellow Breasted Chat:

"Often while passing along some retired lane in the country, have I stopped to listen to the singular notes of this bird as they came suddenly upon my ear, like the whistling of the wings of a dove or teal .. . . causing me to look up in the expectation of seeing some wild fowl flying off before me. . . . One may readily discover the bird's whereabouts by answering him. . . . He will give you some curious specimens of ventriloquism. His shrill whistle will seem far ahead, when on its ceasing you will be greeted with a note not unlike the half-suppressed croak of an old bull-frog, deep in the thicket beside you; if you stop, he raises his key, almost exactly imitating the call of the partridge, varying it with some deep guttural sounds, much like the barking of young puppies. If you happen to be near his mate and her nest, his anxiety becomes very great; he scolds incessantly, mixing up his whistles and croaks into a most singular jargon of sounds. But if you will sit down on the grass and be right quiet, before long his notes will cease, and if you look carefully under the thicket, you will most likely see him, with his tail up and head down, peering at you with his dark eye, from the lower branch of some sumach. If he finds he is discovered, he becomes more bold and will fly out into the air above your head, where with legs hanging straight down, and tail sticking straight up, he will jerk about, rising pretty high with his short concave wings, and then dropping lower and lower when he glides off into the thicket again. On clear moonlight nights his notes may be heard till long after midnight . . . the country people call him the mocking bird.

"This is perhaps the most difficult bird to shoot that we have. . . . Catesby, an Englishman, who spent some time travelling through the country in the 16th century, in his Natural History of the Colonies, says that he tried his best to obtain specimens himself, but could not, and had to apply to the Indians, who with all their ingenuity found it a difficult matter. . . .

"In size he is somewhat less than the cat bird; the color of his back and wings . . . olive green, and his throat and breast bright yellow. In form he differs from all other birds, excepting an East Indian species with which he is arranged in the genus 'Icteria.' Naturalists differ very widely, as to what family this genus should be referred to. His trivial name, 'polyglotta,' indicates his musical powers."

CONTRIBUTIONS TO PALAEONTOLOGY [9]

Cope had been diverted from herpetology, as we have seen, by the arrival of *Amphibamus grandiceps* and had swung to an enthusiasm for palaeontology which resulted in his monumental researches, explorations and publications for various State and National Geological Surveys from 1866 until 1897. Beginning in 1866 he was the first to find along the New Jersey coast remains of the leaping dinosaur, *Laeleps aquilunguis,* and he anticipated Huxley in comparing these reptiles with the birds.[10] In 1871 he extended his investigations into the most arid portion of Kansas and there found remains of the ancient marine monsters, the ram-nosed mosasaur, and the sea-serpent or elasmosaur. Following up Custer's army into the Rocky Mountains between the years 1872 and 1878, he discovered in New Mexico, Colorado and Wyoming, the great *Amphicoelias,* the gigantic *Camarasaurus* and the frill-necked *Agathaumas.* In 1877 he received his first fossils from the Permian of Texas and his investigations thereafter revealed a new fauna, rich in species widely different from any previously known.

Working often alone, except for guides, he was obliged to draw his conclusions from fragmentary and imperfect materials and he felt always the necessity of hastening the publication of his findings that he might be the first to herald them. When a bone came into his hands, Professor Cope slowly turned it over and over to thoroughly comprehend its form and to compare it with its nearest ally, then to throw out a conjecture as to its uses and its relation to the life economy of the animal as a whole. He studied the soil and rocks which had entombed the mighty bones, pictured to himself the muscles and nerves which had clothed them and made possible a locomotion to the methods of which the bones themselves bore mute testimony. His mind's eye saw vividly the muddy shores of the

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[9] See, also, Contributions to Mammalogy, Ichthyology, Geology, and Work with Geological Surveys. Also, Osborn, *Impressions of Great Naturalists.*

[10] *Remarks on Extinct Reptiles which approach Birds,* E. D. Cope, *Proc. Acad. Nat. Sci. Phila.* (Vol. XIX) pp. 234, 235. May 11, 1868.

Texas Permian seas where the fin-backed lizards basked, and the great fresh-water expanses of Wyoming and Montana where the dinosaurs wandered. He spoke of these things graphically and today they are visualized in many of our great museums through his inspiration.

PHYLOGENY OF THE VERTEBRATA

In reconstructing the history of the animals from their bones, Cope, through his great knowledge of anatomy, was also able to connect the ancient species with their modern descendants and to fill in many gaps both in human and animal ancestry. He was fortunate in finding in northwestern New Mexico by far the oldest quadrupeds known at that time, in finding among these the most venerable monkey then known, in describing to the world hundreds of links in the descent of the horses, camels, tapirs, dogs and cats. He worked out (though these views have been modified by later work) the connection between the amphibians and the reptiles and between the amphibians and the true fish, and he was quick as a flash to detect in the paper of some other author the oversight of some link for which he had long been searching.

His final pronouncement of views concerning the phylogeny of the true fishes, amphibians and reptiles was given in the *Proceedings of the American Philosophical Society* for 1892 (pp. 278-281). The ancestral type of the bony fishes was thought to be "probably the Ichthyomous order of the subclass of sharks (Elasmobranchii)." These he selected because "they are hyostylic, and have cranial segmentation, the basioccipital element being conspicuous. The fins are primitive and those of all other types of fishes might have been derived from them." This view is now being modified by the opinion that much of the simplicity of the sharks is degenerate; the Ichthyotomi are now considered as probably the most primitive of known sharks, but too definitely elasmobranchs to be ancestral to the teleostomes and the two are thought to be of equal antiquity palaeontologically.

There remained some doubt in Cope's mind as to the probable ancestry of the batrachia and he remarked "that it cannot be considered to be yet settled." He was at first a supporter of the Haeckelian belief that they had been derived from the Dipnoi or Dipneusta, but later discarded this theory in favor of Theodore Gill's proposal of the Crossopterygians. He suggested particularly the Rhipidopterygia, in which he included the families of Holoptychiidae, Tristichopteridae, Osteolepididae, Coelacanthidae, "and perhaps some others." The origin of the amphibia is now sought in or near the crossopterygians and the osteolepids are believed to be closest to this ancestry of any known forms.

He was less cautious about the reptiles, which at that time were admittedly differentiated from the amphibian stock, although the exact point of departure remained in obscurity, and concluded that the batrachians which were nearest to the reptiles were the "Emblomeri of the Permian epoch." It is now usually accepted that the Emblomeri among the amphibians are closest to the reptiles, perhaps because this term is used for a grade of structure which appears to be primitive for amphibia, but the origin of reptiles is now sought farther back than the Permian.

As to his scientific attainment in the field of taxonomy or classification, apart from his genius, which is indefinable, we signalize his appreciation of the most significant or diagnostic character in a group. Among his fellow-workers in the same field, whether upon the fishes, amphibians, or mammals, he was quick to comprehend and seize upon a strategic position. While others were plodding on serenely in the description of facts, giving all an equal value, Cope, with an eagle eye, would swoop down upon some great distinctive fact and point out its supreme importance. Thus he projected the mammalian order, *Creodonta,* out of numerous forms, such as *Palaeonictis, Hyaenodon, Arctocyon,* which had been discovered and studied for many years in France. It is to be regretted that he did not more willingly surrender some of his own hypotheses. He

clung to his erroneous mechanical explanation of the origin of ungulate foot structure long after it had been disproved by the present writer. Like all of us, perhaps, he loved his own hypotheses, and he once observed in jest in regard to a fossil which had opposed one of his theories, "I wish you would throw that bone out of the window."

He was no respecter of authority *per se*. Even if sometimes mistaken, his fearless criticisms were chiefly animated by high ideals and readiness to change the existing order of things. He was full of cheer and determination when things looked most unpromising, allowing nothing to disturb the composure which is so essential to research.

Contributions to Sociology

As the Copes' only child, Julia, grew up her father became interested in the education of women and through that subject in various other sociological problems. He proceeded to publish his opinions. He believed that women, being the mothers of the race and equal contributors to its development, should enjoy opportunities for intellectual development equal to those of men.[11] He sent his daughter to Miss Burnham's School at Northampton, Massachusetts, stipulating that she should study as much science as possible. Later, in 1885, he transferred her studies to the newly-opened Bryn Mawr College where Woodrow Wilson and other recent graduates of the Johns Hopkins University were young professors. He continually admonished his daughter to study, telling her that the best beloved woman was she who combined beauty with intelligence and an informed mind.

That woman of any race, however, is predestined to a physical and mental inferiority to the man of her own race Cope firmly stated; giving the physical disabilities as "inferior muscular strength and child-bearing"; and the mental disabilities as "inferior mental co-ordination, and greater emotional sensibility

[11] *The Relation of the Sexes to Government*, E. D. Cope. Popular Science Monthly, October, 1888.

which interferes more or less with rational action." He stated the differences between the sexes as follows:[12]

"The struggle with Nature has given the male of man superior muscular strength and superior rationality. Both have been forced upon him, the first by exertion, the second by experience. Necessity has also compelled him to undergo labor of body and of mind for long continued periods, so that his powers of endurance have been cultivated. Knowing the danger of physical conflict with his kind, he has learned to exercise a certain control of his manners and language. As regards women, their maternal instinct and the care of children have cultivated their affections rather than their rational faculties. Their occupations, although often laborious, have been generally less severe than those of men; hence results their inferior muscular strength, which is from two-thirds to one-half that of a man of the same race and condition. Their affectional nature has led women to cultivate the aesthetic and to excel in the adornment of their persons and their homes. For natural reasons they have become more cleanly than man, more refined, and more attentive to small matters. The general effect of the preponderance of the emotional element in the female mind is to render it more liable to the temporary loss of the coordinate action of its parts, than in the man. This fact is illustrated in the greater ease with which women fall into tears, syncope, hysteria, etc. On the other hand women learn many things with great facility, and are quite as skillful in the use of languages as men."

Cope opposed woman suffrage, because he regarded man as woman's natural protector and legislator, because he believed the suffrage should be restricted rather than increased in any case, and because he doubted woman's power of becoming a serious economic or political factor. They would vote through emotional suasion either with or against their husbands and lovers, he thought, and similarly in economics, although some women might be successful in business or professional undertakings, even they would be dependent upon capital produced by masculine effort. Woman suffrage he therefore discarded as an unnecessary promoter of family quarrels, of which there were sufficient causes already, and an instigator of sexual

[12] *The Marriage Problem*, by Prof. E. D. Cope; published from The Open Court of November 15 and 22, 1888, by A. E. Foote, 1223 Belmont Avenue, Philadelphia, 1888.

discord which would react evilly upon the race through the deterioration of feminine attributes.

Regarding marriage Cope was very advanced. He approached the problem almost as a physician approaches the sick, and begged for as calm and unprejudiced a view of the situation as possible. He believed in monogamy as the best economic and psychological adjustment of the biologic problem to civilization. He believed that when monogamy failed two root causes were culpable: mental, spiritual and physical ignorance; and serious divergencies of character and conduct due to ancestry and education. His first reform of the marriage laws concerned unions which involved insane persons, habitual drunkards, and drug addicts: to these when single he would forbid marriage, and when married he would enforce separation "for the all-sufficient reason that such unions cause a great deterioration of the race."

Of normal marriage he remarked: "Eighteen hundred years of Christianity finds us in as great difficulties as ever, but with our sense of justice quickened and our sympathies developed. We have as a basis the fact that most of the white race at least, are capable of a generous and self-sacrificing intersexual passion, which, if treated with reasonable consideration, is of lasting character." Taking this view and the acknowledged failures of the existing system as a starting point, Cope stated his premise: "What is necessary is that matrimonial changes shall be removed from the domain of caprice, and shall be only permitted after a full and fair trial," and expounded his golden mean: the contract marriage. This solution provided for three arbitrarily successive contracts; to have the same value and effect as the existing marriage contract and the same bearing upon support, property and divorce as the laws then prevailing in Pennsylvania, which Cope cited as the most liberal in the country. The time limits of the contracts should increase so as to prevent women of mature age from being deprived of support: the first contract, for previously unmarried persons, should endure for five years and should be renewable only at the desire of both parties; the

second contract should then run for ten or fifteen years and should lapse only at the desire of both parties; the third contract for permanent relations should then be available. In cases of second marriage the longest contract next in order for either party should be obligatory, except in cases where one person had hitherto been unmarried when the previous time contract of the other should be duplicated for the new marriage. Divorce at the expiration of a contract should be granted without publicity, the custody of children being settled as under prevailing laws. A man should be held responsible for the support of his children after divorce, but not of his wife if she be childless. In that case, as her divorce was of her own choosing, she should support herself or be supported by her family.

Throughout the discussion of the marriage problem, education and suffrage, Cope was insistently the biologist, interpreting his sociology by the laws of nature and led to optimism by his belief in evolution. He was an intense Lamarckian and stated in his "*Origin of the Fittest*," "I have learned the connection between the motion of animals and the development of their structure by my studies of palæontology. It is a satisfaction to me to be able to prove the fatherhood of mind or living personality over living nature. It will be the next step to prove that it has been so over dead nature, also. . . . In the proper way and at the proper time mind controls. To find out how this is and when and where, is the great problem of science, also therefore of progress and prosperity."

Cope was a theist in evolution, probably because so long as his orthodox Quaker father lived he was continually requested to reconcile his theories with the religious views in which he had been strictly trained. His affection for his father and his real devotion to a faith, which was after all less troubled by dogma than many sects of his generation, helped him. In fact he justified his early acceptance of the Darwin theory in 1871 as a "Shaker of false faiths and an aid to that which is founded on a rock, that that which cannot be shaken may remain." After his father's death he began to feel that the need of curtailing

his views to avoid controversy and scandal in a small circle was too severe a strain upon his adventurous imagination. He accordingly resigned from the Society of Friends in 1878, but remained a theist in philosophy and a creative evolutionist in scientific theory.

CONCLUSION

The most conspicuous feature of Cope's character from boyhood upward was independence; seldom has a face reflected a character more fully. His square and prominent forehead suggested his vigorous intellect and marvelous memory; his brilliant eyes were the media of exceptional keenness of observation; his prominent chin was in traditional harmony with his aggressive spirit. From this rare combination of qualities so essential to free investigation sprang his scientific genius.

Appreciation of greatness is a mark of the civilization and culture of a people. Cope's monumental work, preserved in thousands of notes, short papers, and memoirs, and in three bulky government quartos, constitutes his assurance of enduring fame. Some of his countrymen, and even of his fellow-workers, allowed certain of his characteristics to obscure his stronger side in their estimate of him and his works, and during his life he received few of the honors such as foreigners are wont to bestow upon their countrymen of note. When we think more deeply of what really underlies human progress, we realize that only to a few men with the light of genius is it given to push the world's human thought along, and that Edward Drinker Cope was one of these men.

We may contrast three great Academicians: Joseph Leidy, Edward Drinker Cope and Othniel Charles Marsh. Whereas in Leidy we had a man of the exact observer type, Cope was a man who loved speculation. If Leidy was the natural successor of Cuvier, Cope was the natural successor of Lamarck. Leidy, in his contributions to the academy, covered the whole world of nature, from the Protozoa and Infusoria up to man, and he

lived as the last great naturalist in the world of the old type who was able by both capacity and training to cover the whole field of nature. Cope, in contrast, mastered—and this mastery in itself was a wonderful achievement—the entire domain of vertebrates from the fishes up. Marsh, with less breadth and less ability, nevertheless was a palaeontologist of a very high order and had a genius for appreciating what might be called the most important thing in science. He always knew where to explore, where to seek the transition stages, and he never lost the opportunity to point out at the earliest possible moment the most significant fact to be discovered and disseminated.

It is most interesting to contrast the temperament of these three men, Joseph Leidy, Edward Drinker Cope and Othniel Charles Marsh. They were as different as any three men could possibly be made, both by nature and nurture. As Professor Edward Smith said, in one of his addresses on Leidy, "scientists are only mortals after all." Your scientific genius may hitch up with a star on one hand and with an anchor on the other. Whereas Leidy was essentially a man of peace, Cope was what might be called a militant palaeontologist; whereas Leidy's motto was peace at any price, Cope's was war whatever it cost. I do not know that I can find from Shakespeare any characterization of Joseph Leidy, but I think in *Henry IV* there is a very apt characterization of my friend Edward D. Cope:

> I am not yet of Percy's mind, the Hotspur of the north; he that kills me some six or seven dozen of Scots at a breakfast, washes his hands and says to his wife, "Fie upon this quiet life! I want work."

Perhaps there was a scientific providence in all this; perhaps such antagonistic spirits were necessary to enliven and disseminate interest in this branch of science throughout the country. The subtle combative quality in a palaeontologist is a strange quality; it is a strange inversion, because the more ancient and difficult the study, the more refractory the fossil, the greater the animation of discussion regarding its relationships. From this subtle ferment there arose the famous rivalry which existed not between Leidy and either of the others, because it was impossible to quarrel with Leidy, but between Cope, the descendant of a Quaker family, and Marsh the nephew of a great philan-

thropist. This rivalry was tonic to Cope and although in his eagerness to publish his discoveries and theories before Marsh could produce similar material he made careless mistakes, still "the scowl of his foe" (Marsh) remained, as in the Celtic poem, "the sun which caused him to grow."

Bibliography of Edward Drinker Cope

1859-1915

BY HENRY FAIRFIELD OSBORN AND ASSISTANTS

INTRODUCTION

This bibliography has been rearranged from the manuscript copy of a "Bibliography of the Published Writings of Edward Drinker Cope, 1859-1899," by Anna M. Brown.

In the revision material from the bibliography included in Dr. O. P. Hay's "Bibliography and Catalogue of the Fossil Vertebrata of North America,"[1] and Persifor Frazer's "Catalogue chronologique des publications de Edward Drinker Cope"[2] has been incorporated. Indebtedness must also be acknowledged to Mr. F. W. Ashley of the Library of Congress, to Dr. Witmer Stone of the Academy of Natural Sciences of Philadelphia, to Dr. W. P. Wilson of the Commercial Museum, Philadelphia, to Mr. John Ashurst of the Free Library of Philadelphia, and to Mr. Charles W. Johnson of the Boston Society of Natural History who have most kindly helped both to verify and to locate references.

In the arrangement of the titles an effort has been made to keep to the following rules:

I. Dates
   A. So far as can be ascertained the titles are arranged in chronological sequence in accordance with their respective dates of publication.
      1. Dates of publication are taken from

[1] Bibliography and Catalogue of the Fossil Vertebrata of North America. *Bull. U. S. Geol. Survey*, No. 179, 1902.

[2] Catalogue chronologique des publications de Edward Drinker Cope . . . *Extrait, Annales Soc. géol. de Belgique*, t. XXIX, Bibliographie, pp. BB3-BB77. Liége, 1902.

a. Dates on the brochures.

b. Dates published by the Academy of Natural Sciences of Philadelphia in "Index to the Scientific Contents of the Journal and Proceedings of the Academy of Natural Sciences of Philadelphia. Published in Commemoration of the Centenary of the Academy, March 21, 1912."

c. Dates of acknowledgment for the various parts of the publications of the American Philosophical Society as published in their Proceedings.

B. In cases where an article has appeared in instalments covering two or more months the *date of the first instalment* has been adopted.

C. When no date of publication could be found

1. Verbal communications were listed under the dates of the proceedings.
2. Volumes were placed at the beginning of the year.
3. Those titles having the month but not the day of publication were placed at the beginning of the month.

D. Dates following volumes are those of the year in which the verbal proceedings were held. When there is a discrepancy between this date and the one selected as the index date, the latter is, to the best of belief, that of actual publication.

E. An abstract of an article appearing previous to the publication of the full article is separately listed. (See, II C.)

F. Titles found in the manuscript but impossible to locate and undated manuscripts of Cope's have been placed together, without numbers, at the beginning of the bibliography.

II. Titles

A. Published titles stand as printed save for uniformity of capitalization.

B. Verbal communications and untitled editorials are titled as follows:

1. According to the titles published in the indices of the volumes, except in cases where the title failed to agree with the subject of the communication.
2. According to some title published later as in the "Index" of the Academy.
3. By supplying a title enclosed in ( ), using in almost all cases those in Miss Brown's bibliography.

C. Titles of abstracts, when changed from but of *later date of publication* than the original are indicated under the original article.

III. Abbreviations

A. The titles of all publications are abbreviated in accordance with the schemes most commonly used.

e. g. Amer. Journ. Sci.—American Journal of Science
Amer. Nat.—American Naturalist
Ann. & Mag. Nat. Hist.—Annals and Magazine of Natural History
Bull. U. S. Nat. Museum.—Bulletin of the United States National Museum
Bull. Geol. Soc. Amer.—Bulletin of the Geological Society of America
Journ. Acad. Nat. Sci. Phila.—Journal of the Academy of Natural Sciences of Philadelphia
Lippincott's Mag.—Lippincott's Magazine
Nat. Hist. Rev.—Natural History Review (published in London)
Pal. Bull.—Paleontological Bulletin
Proc. A. A. A. S.—Proceedings of the American Association for the Advancement of Science
Proc. Acad. Nat. Sci. Phila.—Proceedings of the Academy of Natural Sciences of Philadelphia
Proc. Amer. Philos. Soc.—Proceedings of the American Philosophical Society
Proc. U. S. Nat. Museum—Proceedings of the United States National Museum
Proc. Boston Soc. Nat. Hist.—Proceedings of the Boston Society of Natural History
Proc. Zool. Soc.—Proceedings of the Zoological Society of London
Smithsonian Contrib. to Knowledge—Smithsonian Contributions to Knowledge
Southern Mag.—Southern Magazine
Trans. Acad. Nat. Sci. Phila.—Transactions of the Academy of Natural Sciences of Philadelphia
Trans. Amer. Entomol. Soc.—Transactions of the American Entomological Society
Trans. Amer. Philos. Soc.—Transactions of the American Philosophical Society.
Zool. Anz.—Zoologischer Anzeiger

1. In cases such as the Annals and Magazine of Natural History and the American Journal of Science where the title of the publication has undergone change the title now in use is the one chosen throughout the bibliography.

B. Miscellaneous abbreviations

1. (Hay) means that the preceding note or succeeding title is quoted in Hay's "Bibliography and Catalogue of the Fossil Vertebrata of North America."
2. * means not personally seen

TITLES OF E. D. COPE, NOT DISCOVERED, JULY 1, 1921

Some Points in the Zoology and Geology of Glycaphuatl, by Robert Ramrod, A. E. C.

A Satire on the Philadelphia Academy. Evidently seen by Persifor Frazer since it is quoted by him in the *American Geologist,* Vol. 26, 1900, pp. 70, 71. No trace could be found.

ORGANIC MATTER

Supposed to be in the *New Review* (Philadelphia), Vol. I, No. 3, Sept. 19, 1895, pp. 20, 21. Not in the publication.

BIOLOGY

Supposed to be in the *New Review* (Philadelphia), Vol. II, No. 1, 1896, p. 212. Not in the publication.

A Bibliography of the Chelonia (MSS.). Now in possession of the Osborn Library of Vertebrate Paleontology.

A collected volume of manuscript. Contents: Catalogue of Reptilia of the Upper Amazon.

BIBLIOGRAPHY

1859.1 April 26 — On the Primary Divisions of the Salamandridæ, with Descriptions of Two New Species. *Proc. Acad. Nat. Sci. Phila.* Vol. XI, 1859, pp. 122-128.

An annotated synopsis of the subfamilies and genera with descriptions of the new species *Amblystoma conspersum* and *Desmognathus ochrophaea* from Pennsylvania.

1860.2 Jan. 12 — Notes and Descriptions of Foreign Reptiles. *Proc. Acad. Nat. Sci. Phila.* Vol. XI, 1859, pp. 294-297.

Tortoises and a crocodile from West Africa, including the new genus *Heptathyra* of the former and a new genus of snake, *Olisthenes,* from South America.

.3 March 30 — Catalogue of the Venomous Serpents in the Museum of the Academy of Natural Sciences of Philadelphia, with Notes on the families, genera and species. *Proc. Acad. Nat. Sci. Phila.* Vol. XI, 1859, pp. 332-347.

.4 April 13 — Supplement to "A Catalogue of the Venomous Serpents in the Museum of the Academy of Natural Sciences of Philadelphia." *Proc. Acad. Nat. Sci. Phila.* Vol. XII, 1860, pp. 72-74.

With a key to the genus *Elaps*, and a description of a new species, *Elaps melanogenys*.

.5 April 13 Catalogue of the Colubridæ in the Museum of the Academy of Natural Sciences of Philadelphia. Part I. Calamarinæ. *Proc. Acad. Nat. Sci. Phila.* Vol. XII, 1860, pp. 74-79.
Including description of the new genus *Tropidoclonion* and several new species.

.6 Nov. 15 Catalogue of the Colubridæ in the Museum of the Academy of Natural Sciences of Philadelphia, with Notes and Descriptions of New Species. Part II. *Proc. Acad. Nat. Sci. Phila.* Vol. XII, 1860, pp. 241-266.
Describing the new genera *Pariaspis, Cemophora, Hypsiglena, Coniophanes* Hallowell MSS., *Pliocerus* and *Eumesodon.*

.7 Nov. 15 Notes and Descriptions of New and Little Known Species of American Reptiles. *Proc. Acad. Nat. Sci. Phila.* Vol. XII, 1860, pp. 339-345.
Mostly from the Xantus collection from Lower California. A new genus of snake, *Chilomeniscus*, is described from that peninsula.

.8 Dec. An Enumeration of the Genera and Species of Rattlesnakes, with Synonymy and References. *Smithsonian Contrib. to Knowledge*, Vol. XII, 1860, Art. VI, Appendix A, pp. 119-126.
Including the first mention, from MSS. (without description), of Kennicott's *Crotalus lepidus.*

1861.9 Jan. 18 Descriptions of Reptiles from Tropical America and Asia. *Proc. Acad. Nat. Sci. Phila.* Vol. XII, 1860, pp. 368-374.
Including the new family *Adenomidæ* and genus *Ademomus* from Ceylon, the new skink, *Siderolampsus* from Mexico and the new snake genus *Amastridium* from New Granada (Colombia).

.10 Jan. 18 Report upon the Reptiles of the North Pacific Exploring Expedition under Command of Capt. John Rogers, U. S. N., by Edward Hallowell (E. D. Cope, editor). *Proc. Acad. Nat. Sci. Phila.* Vol. XII, 1860, pp. 480-510.
Collections of reptiles and amphibians from Nicaragua, California, Oceania (Hawaiian Islands), New Holland (Australia), Loo-Choo, Japan, China, Java, Cape of Good Hope, and Madeira, with an index of species.

.11 March 31 Descriptions of New Species of the Reptilian Genera *Hyperolius, Liuperus* and *Tropidodipsas.* *Proc. Acad. Nat. Sci. Phila.* Vol. XII, 1860, pp. 517, 518.
From Liberia, Buenos Aires and Honduras, respectively.

.12 List of the recent species of Emydosaurian Reptiles in the
March Museum of the Academy of Natural Sciences. *Proc. Acad.*
31 *Nat. Sci. Phila.* Vol. XII, 1860, pp. 549, 550.
With descriptions of a new genus *Osteolaemus* of the *Crocodilidæ* from West Africa, and a new snake, *Mecistops bathyrhynchus* of unknown locality.

.13 Catalogue of the Colubridæ in the Museum of the Academy
March of Natural Sciences of Philadelphia. Part III. *Proc. Acad.*
31 *Nat. Sci. Phila.* Vol. XII, 1860, pp. 553-566.
Including descriptions of the new genera *Prymnomidon* from Siam and *Zaocys* from Ningpo, China.

.14 Remarks on Reptiles (Changes in Nomenclature: Species of
June *Tantilla:* Specific Characters of *Lepidosternum floridanum*).
30 *Proc. Acad. Nat. Sci. Phila.* Vol. XIII, 1861, pp. 73-75.
Gives a synopsis of the genus *Tantilla.*

.15 Remarks on Reptiles (*Diphalus: Amphisbaena angustifrons:*
June *Loxocemus* Cope). *Proc. Acad. Nat. Sci. Phila.* Vol. XIII,
30 1861, pp. 75-77.
West Indies, Buenos Aires and San Salvador.

.16 On an Iguana from Andros Island. *Proc. Acad. Nat. Sci.*
Sept. *Phila.* Vol. XIII, 1861, p. 123.
30 *Cyclura bacolopha* Cope.

.17 On Amblystoma from Chester Co., Pennsylvania. *Proc.*
Sept. *Acad. Nat. Sci. Phila.* Vol. XIII, 1861, pp. 123, 124.
30 A new species of Amblystoma, *Amblystoma microstomum,* from Ohio.

.18 Notes and Descriptions of Anoles. *Proc. Acad. Nat. Sci. Phila.* Vol. XIII, 1861, pp. 208-215.
The Academy of Natural Sciences of Philadelphia acknowledges no month for this signature. A preliminary paper on the anoline Squamidæ mostly from Cuba.

.19 Contributions to the Ophiology of Lower California, Mexico
Dec. and Central America. *Proc. Acad. Nat. Sci. Phila.* Vol.
28 XIII, 1861, pp. 292-306.
With some general remarks on distribution and the dividing line between the neotropical and nearctic groups of faunæ.

.20 On the Reptiles of Sombrero and Bermuda. *Proc. Acad.*
Dec. *Nat. Sci. Phila.* Vol. XIII, 1861, pp. 312-314.
28 A description of two new species *Ameiva corvina* and *Plestiodon longirostris.*

1862.21 March 31 On the Genera *Panolopus*, *Centropyx*, *Aristelliger* and *Sphaerodactylus*. *Proc. Acad. Nat. Sci. Phila.* Vol. XIII, 1861, pp. 494-500.

With a synopsis of species.

.22 March 31 Observations upon certain Cyprinoid Fish in Pennsylvania. *Proc. Acad. Nat. Sci. Phila.* Vol. XIII, 1861, pp. 522-524.

Chrosomus eos and *Leucosomus rhothius* (*Cyprinella analostana* Gerard of Potomac basin) found in Susquehanna basin.

.23 March 31 On *Elapomorphus*, *Sympholis*, and *Coniophanes*. *Proc. Acad. Nat. Sci. Phila.* Vol. XIII, 1861, p. 524.

Dividing *Elapomorphus* into three genera *E.*, *Phalotris* and *Apostolepis*. Specimens described from Paraguay and Guadalaxara, Mexico.

.24 April 25 On the Dentition of *Herpeton tentaculatum*, and on the Habitat of *Gerarda prevostiana* and *Rhabdosoma lineatum*. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, p. 1.

From Siam, Philippine Islands (?) and Trinidad, respectively.

.25 April 25 Synopsis of the Species of *Holcosus* and *Amevia*, with Diagnoses of new West Indian and South American Colubridæ. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, pp. 60-82.

The H. and A. from West Indies, Central and South America.

.26 April 25 On some New and Little Known American Anura. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, pp. 151-159.

From Cuba, New Providence Isl., St. Thomas, New Grenada (Colombia), Paraguay, Panama and Nicaragua.

.27 Contributions to Neotropical Saurology. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, pp. 176-188.

The Academy of Natural Sciences acknowledges no date (month or day) for these pages. See the "Index," p. xiii. From New Grenada (Colombia), Paraguay, Central America and the West Indies. With a synopsis of the skink genus *Mabuia*.

.28 On *Neosorex albibarbis*. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, pp. 188, 189.

The Academy of Natural Sciences acknowledges no date (month or day) for these pages. See the "Index," p. xiii.

.29 On *Lacerta echinata* and *Tiliqua dura*. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, pp. 189-191.

The Academy of Natural Sciences acknowledges no date

(month or day) for these pages. See "Index," p. xiii. Both from West Africa. Other additions to the "Catalogues of West African reptiles recently published by Drs. Gray and Duméril."

.30 On *Carphotis harpesti*. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, p. 249.
The Academy of Natural Sciences acknowledges no date (month or day) for these pages. See the "Index," p. xiii. A specimen of this Dum. and Bib. species discovered in Texas is placed in the genus *Virginia*.

.31 Oct. 28 Notes upon some Reptiles of the Old World. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, pp. 337-344.

.32 Oct. 28 On a Cuban Bufanoid: *Peltaphryne empusa*. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, p. 344.
First characterization of this genus.

.33 Oct. 28 Catalogue of the Reptiles obtained during the Explorations of the Parana, Paraguay, Vermejo and Uraguay Rivers, by Capt. Thos. J. Page, U. S. N.; and of those procured by Lieut. N. Michler, U. S. Top. Eng., Commander of the Expedition conducting the Survey of the Atrato River. *Proc. Acad. Nat. Sci. Phila.* Vol. XIV, 1862, pp. 346-359.
With a synopsis of the Bufonidæ.

1863.34 April 3 On Trachycephalus and on South American Batrachia. *Proc. Acad. Nat. Sci. Phila.* Vol. XV, 1863, p. 26.
Corneöus thickening on interior metatarsus of *Trachycephalus* during breeding season. Manubrium sterni present in certain South American Bufones.

.35 May On Part II of Prof. G. Jan's Prodromo della Iconografia Generale degli Ofidi. [Review]. *Amer. Journ. Sci.*, 2d Ser. Vol. XXXV, 1863, pp. 455-458.
Discussion and corrections on Calamaridæ and a new synopsis of the Probletorhinidæ.

.36 June 8 On *Hololepis simus*. *Proc. Acad. Nat. Sci. Phila.* Vol. XV, 1863, p. 42.
New species from Cedar Swamps, New Jersey.

.37 June 8 On *Trachycephalus, Scaphiopus* and other American Batrachia. *Proc. Acad. Nat. Sci. Phila.* Vol. XV, 1863, pp. 43-54.
Mostly from Tropical America. Synopses of Trachycephalus and Scaphiopus.

.38 June 9 On a Species of Vipera hitherto unknown. *Proc. Zool. Soc.* 1863, pp. 229, 230, one figure. (Reprinted, *Ann. & Mag. Nat. Hist.*, 3d. Ser., Vol. XIII, 1864, pp. 181, 182, one figure).

V. confluenta.

.39 July 13 Descriptions of new American Squamata, in the Museum of the Smithsonian Institution, Washington. *Proc. Acad. Nat. Sci. Phila.* Vol. XV, 1863, pp. 100-106.

Mostly from Tropical America including several of Xantus' specimens from Cape St. Lucas, Lower California.

1864.40 Sept. 30 Contributions to the Herpetology of Tropical America. *Proc. Acad. Nat. Sci. Phila.* Vol. XVI, 1864, pp. 166-181.

.41 Sept. 30 On the Limits and Relations of the Raniformes. *Proc. Acad. Nat. Sci. Phila.* Vol. XVI, 1864, pp. 181-183.

.42 Sept. 30 On the Characters of the Higher Groups of Reptilia Squamata—and especially of the *Diploglossa. Proc. Acad. Nat. Sci. Phila.* Vol. XVI, 1864, pp. 224-231.

.43 Sept. 30 On a Blind Silurid, from Pennsylvania. *Proc. Acad. Nat. Sci. Phila.* Vol. XVI, 1864, pp. 231-233.

Gronias nigrilabris Cope N. Sp. with rudimentary eyes, and *Ethostoma peltatum* Stauffer N. Sp., from Conestoga Creek, Lancaster Co., Pa. *Pœcilichthys mesœus* Cope N. Sp. from Platte River, Fort Kearney, Neb.

1865.44 Jan. ? Sketch of the Primary Groups of *Batrachia salientia. Nat. Hist. Rev.* (London), Vol. V, 1865, pp. 97-120.

.45 Feb. 13 Partial Catalogue of the Cold-Blooded Vertebrata of Michigan. *Proc. Acad. Nat. Sci. Phila.* Vol. XVI, 1864, pp. 276-285.

From collections of the Flint Scientific Institute, the State Agricultural College. Several new species. Several specimens from Pennsylvania and Kansas discussed in footnotes.

.46 Aug. 7 Partial Catalogue of the Cold-Blooded Vertebrata of Michigan. Part II. *Proc. Acad. Nat. Sci. Phila.* Vol. XVII, 1865, pp. 78-88.

Continuation of preceding. Several new species described in footnotes. On p. 85 "Note on fishes brought from Platte River, near Fort Riley, by Dr. Wm. A. Hammond." On pp. 87-88 "Supplementary note on a peculiar genus of Cyprinidæ—*Ericymba buccata* Cope, N. G. et Sp."

.47 Oct. 16 On *Amphibamus grandiceps*, a new Batrachian from the Coal Measures. *Proc. Acad. Nat. Sci. Phila.* Vol. XVII, 1865, pp. 134-137.

This is Cope's first palaeontological contribution. Moodie remarks,[13] "The publication of the type species of this genus began the researches of Professor Cope on the extinct amphibia of North America, which he continued for so many years with such excellent results. The description was based on a single specimen, belonging to Mr. Joseph Evans of Morris, Illinois, who loaned it to Dr. Worthen for the Illinois Geological State Survey, in order that it might be described. The type has been destroyed by fire; so I am informed by Mr. L. E. Daniels of Rolling Prairie, Indiana. There are two other known specimens of the species. One is in the collection of Mr. Daniels, and the other No. 794 of the Yale University Museum." The genus is an important one among fossil amphibia and is made by Dr. Moodie the type of a distinct family.

.48 Oct. 16 Note on a Species of Whale occurring on the Coasts of the United States (Title given in Index for Vol. XVII, as follows: Note on a Species of Whale caught in the River Delaware). (*Balæna cisarctica.*) *Proc. Acad. Nat. Sci. Phila.* Vol. XVII, 1865, pp. 168, 169.

.49 Dec. 26 Note on a Species of Hunchback Whale. *Proc. Acad. Nat. Sci. Phila.* Vol. XVII, 1865, pp. 178-181.

Megaptera osphyia.

.50 Dec. 26 Third Contribution to the Herpetology of Tropical America. [Frazer (1902) added to this title the following sub-title:—With a Synopsis of the Genera *Hylidae.*] *Proc. Acad. Nat. Sci. Phila.* Vol. XVII, 1865, pp. 185-198.

With a list of species sent by Dr. Sartorius to the Smithsonian Institution from near Vera Cruz and the table-land and southern mountains of Mexico. Also a synopsis of the genera of Hylidæ.

.51 Dec. 26 A Contribution to a Knowledge of the *Delphinidæ*. *Proc. Acad. Nat. Sci. Phila.* Vol. XVII, 1865, pp. 198-204.

1866.52 Supplement to the Description of Vertebrates. *Geological Survey of Illinois*, A. H. Worthen, Director, Vol. II, 1866, pp. 135-141, Pl. XXXII and 1 woodcut.

Amphibamus grandiceps redescribed and figured. See 47.

[13] Moodie, R. L., 1916, The Coal Measures Amphibia of North America. Carnegie Institution Publication No. 238, p. 126.

.53 Observations on the Skeleton of a Seal, and on the Crania of Cetaceans of the United States Coast, with Remarks on the Species of the Latter. *Proc. Acad. Nat. Sci. Phila.* Vol. XVII, 1865, pp. 273, 274.

The original, verbal communication, is not indexed. The title was given by Frazer (1902), but in the Index of the Academy (1913) the title is given as: On a Species of Seal and on Cetaceans. No date of publication acknowledged by the Academy of Natural Sciences, see, "Index," p. xiii. It seems obvious that the more likely date for this signature is early in 1866, since the preceding signature was dated December 26, 1865, and the subsequent signature for the earliest part of Vol. XVIII is acknowledged June 11, 1866.

.54 Observations on the Geographical Distribution of Some Fresh-water Fishes. *Proc. Acad. Nat. Sci. Phila.* Vol. XVII, 1865, p. 274.

No date of publication acknowledged by the Academy of Natural Sciences. See 53, note. Untitled verbal communication. Present title given by Frazer (1902). Changed in the Index (1913) to: On Geographical Distribution of Certain Fishes. Contrast in fish faunas of Coastal Plain and Piedmont of Atlantic Slope of U. S.

.55 Second Contribution to a History of the Delphinidæ. *Proc. Acad. Nat. Sci. Phila.* Vol. XVII, 1865, pp. 278-281.

No date of publication acknowledged by the Academy of Natural Sciences. See 53, note.

.56 June 11 Remarks on a Species of Nautilus, *Aturia,* from the New Jersey Cretaceous. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, pp. 3, 4.

Title in Index: On an Aturia from the Marl of New Jersey.

.57 June 11 Description of the cranium of a Black-Fish from Delaware Bay. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, pp. 7, 8.

(*Globicephalus.*)

.58 July On the Structures and Distribution of the Genera of the Arciferous Anura. *Journ. Acad. Nat. Sci. Phila.,* Ser. 2, Vol. VI, 1866, pp. 67-112, Pl. XXV. (Separates, July, 1866.)

.59 Fourth Contribution to the Herpetology of Tropical America. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, pp. 123-132.

No date acknowledged by the Academy of Natural Sciences. See "Index," p. xiii. With descriptions of the new lacertilian genus *Cachryx,* and *Colostethus* of the Ranidæ.

.60 On Some Vertebrates from the Mesozoic Red Sandstone. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, pp. 249, 250.
No date acknowledged by the Academy. See "Index," p. xiii. Phœnixville, Pa., fossils. Description of *Mastodonsaurus durus* (=*Eupelor durus*).

.61 Remarks on the Remains of a Gigantic Extinct Dinosaur from the Cretaceous Greensand of New Jersey. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, pp. 275-279.
No date acknowledged by the Academy. See "Index," p. xiii. Description of *Lœlaps aquilunguis.*

1867.62 Feb. 13 Remarks on the Geological Horizon of the Mesozoic Sandstone of Pennsylvania. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, p. 290.
Pterodactylus longispinis from Pa. Trias. No description.

.63 Feb. 13 Third Contribution to the History of the Balaenidæ and Delphinidæ. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, pp. 293-300.
Remarks on eight species, five of them new.

.64 Feb. 13 On the Reptilia and Batrachia of the Sonoran Province of the Nearctic Region. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, pp. 300-314.
Hyla curta Cope. On a collection made along the Mexican border by Dr. Coues, and others. General discussion of the distribution of species in the Sonora province. Includes a synopsis of the genus *Caudisoma* (*Crotalus*).

.65 Feb. 13 On Anatomical Peculiarities in Some Dinosauria. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, pp. 316, 317. (Title in Index: On *Lelaps.*)
Relations of tibia and fibula in *Lœlaps.*

.66 Feb. 13 Fifth Contribution to the Herpetology of Tropical America. *Proc. Acad. Nat. Sci. Phila.* Vol. XVIII, 1866, pp. 317-323.
New species and a new genus of snakes, *Mesopeltis,* all from Mexico.

.67 March The Fossil Reptiles of New Jersey. *Amer. Nat.,* Vol. I, 1867, pp. 23-30.
General account of the Cretaceous reptilia.

.68 June (?) On Euclastes, a Genus of Extinct Chelonidæ. *Proc. Acad. Nat. Sci. Phila.* Vol. XIX, 1867, p. 31.
No date acknowledged by the Academy. See "Index," p. xiii. Skull from Cretaceous of New Jersey. No description except length and breadth of skull

.69 June (?) On *Megaptera braziliensis. Proc. Acad. Nat. Sci. Phila.* Vol. XIX, 1867, p. 32.
No date acknowledged by the Academy. See "Index," p. xiii. Nine lines describing a young skeleton presented to the Academy.

.70 July 20 On Euclastes, a Genus of Extinct Chelonidæ. *Proc. Acad. Nat. Sci. Phila.* Vol. XIX, 1867, pp. 39-42.
See 68 for original notice. Adequate description here.

.71 Aug. On the Families of the Raniform Anura. *Journ. Acad. Nat. Sci. Phila.*, Ser. 2, Vol. VI, 1867, pp. 189-206. (Separates, August, 1867.)

.72 Nov. 1 On a Collection of Reptiles from Owen's Valley, California, made by Dr. G. H. Horn, with Remarks on the Origin of Species. *Proc. Acad. Nat. Sci. Phila.* Vol. XIX, 1867, pp. 85, 86.
Notes occurrence of *Scaphiropus holbrookii* near Schuylkill, New York. Compared the genera *Hyla, Scytopis, Osteocephalus* and *Trachycephalus,* which he considered represented a natural series measured by the relative degree of ossification of the cranium.

.73 Nov. 1 A New Genus of Cyprinoid Fishes from Virginia. *Proc. Acad. Nat. Sci. Phila.* Vol. XIX, 1867, pp. 95-97.
Phenacobius teretulus N. G. et Sp., and *P. uranops,* from southeastern Va.

1868.74 Feb. Note on the Fossil Reptiles near Fort Wallace. Le Conte: *Notes on the Geology of the Survey for the Extension of the Union Pacific Railway, E. D., from the Smoky Hill River, Kansas, to the Rio Grande.* Philadelphia, 1868, p. 68.

.75 May 11 Remarks on Four Species of Extinct Mammalia from the Miocene Deposits in Charles County, Maryland. *Proc. Acad. Nat. Sci. Phila.* Vol. XIX, 1867, pp. 131, 132.
Rhabdosteus described.

.76 May 11 Remarks on the Cave Contents in Southwestern Virginia. *Proc. Acad. Nat. Sci. Phila.* Vol. XIX, 1867, pp. 137, 138.
Brief notice of fossils in cave, Wythe Co.

.77 May 11 An Addition to the Vertebrate Fauna of the Miocene Period, with a Synopsis of the Extinct Cetacea of the United States. *Proc. Acad. Nat. Sci. Phila.* Vol. XIX, 1867, pp. 138-156.
Thirty-three species of Elasmobranchii and one Teleost (*Sphyræna speciosa*) determined by fossil teeth from Charles Co., Maryland. Two species of *Thecachampsa* based on isolated teeth; review of American fossil Cetacea, with descrip-

tion of several new species, types in the Philadelphia Academy collection.

.78 On the Genera of Fresh-Water Fishes *Hysilepis,* Baird, and
May *Photogenis* Cope, their Species and Distribution. *Proc. Acad.*
11 *Nat. Sci. Phila.* Vol. XIX, 1867, pp. 156-166.
New species are: *Cyrinella cercastigma; Hypsilepis coccogenis; H. galactuons, H. ardens; Phologenis telescopus, P. leucoidus, and P. scabriceps.*

.79 A Review of the Species of the *Amblystomidæ. Proc. Acad.*
May *Nat. Sci. Phila.* Vol. XIX, 1867, pp. 166-211.
11 With notes on the anatomy and metamorphosis.

.80 On the Habits of a Tipulideous Larva. *Proc. Acad. Nat.*
May *Sci. Phila.* Vol. XIX, 1867, pp. 222-226.
11

.81 Remarks on Extinct Reptiles which approach Birds. *Proc.*
May *Acad. Nat. Sci. Phila.* Vol. XIX, 1867, pp. 234, 235.
11 Birdlike characters in *Lælaps* and *Compsognathus.*

.82 Observations on some Vertebrata from Western Nevada and
June Northern Lower California. *Proc. Acad. Nat. Sci. Phila.*
8 Vol. XX, 1868, p. 2.
Including two new species of boas of the genus *Lichanura.*

.83 Observations on the Living Fauna of Caves in Southwestern
June Virginia. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp.
8 85, 86.

.84 The Birds of Palestine and Panama Compared. *Amer. Nat.*
Sept. Vol. II, 1868, pp. 351-359.

.85 Remarks on a new Enalisaurian. *Proc. Acad. Nat. Sci. Phila.*
Nov. Vol. XX, 1868, pp. 92, 93.
9 *Elasmosaurus platyurus* Cope, preliminary description.

.86 An Examination of the Reptilia and Batrachia obtained by
Nov. the Orton Expedition to Ecuador and the Upper Amazon,
9 with Notes on Other Species. *Proc. Acad. Nat. Sci. Phila.*
Vol. XX, 1868, pp. 96-140.
Including new saurian genus *Opheognomon.* Synopses of the genera *Leptognathus* and *Pithecopus, Liocephalus, Celestus, Xenodon.*

.87 A New Genus of Chelonidæ, *Osteopygis,* from the New
Nov. Jersey Cretaceous Green-Sand. *Proc. Acad. Nat. Sci. Phila.*
9 Vol. XX, 1868, p. 147.
Genotype in the Academy collections.

.88 Nov. 9 On the Vertebræ of a Serpent from the Green-Sand of New Jersey. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, p. 147. (Index title: On Fossil Snakes from New Jersey.)

Palæophis littoralis, Cope.

.89 Nov. On the Genus *Lælaps*. *Amer. Journ. Sci.*, Ser. 2, Vol. XLVI, No. 138, 1868, pp. 415-417.

.90 Dec. 2 On the Distribution of Fresh-Water Fishes in the Allegheny Region of Southwestern Virginia. *Journ. Acad. Nat. Sci. Phila.*, Ser. 2, Vol. VI, pp. 207-247. (Separates, December, 1868.)

Systematic list of the species; description of new species; and discussion of distribution due to geological and physiographical causes.

.91 Dec. (?) Synopsis of the Extinct Reptilia found in the Mesozoic and Tertiary Strata of New Jersey. *Geology of New Jersey.* George H. Cook, State Geologist, 1868, Appendix B, pp. 733-738.

.92 Dec. 2 Synopsis of the Extinct Mammalia of New Jersey. *Geology of New Jersey.* George H. Cook, State Geologist, 1868, Appendix C, pp. 739-742.

.93 Dec. 2 On the Fresh-Water Origin of Certain Deposits in West New Jersey. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp. 157, 158.

Raritan clays.

.94 Dec. 2 On Some Remains of Extinct Cetacea from the Miocene Beds of Maryland. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp. 159, 160.

Two new species described. *Agaphelus* (modem) N. G.

.95 Dec. 2 On New Species of Extinct Reptiles, (*Clidastes iguanavus* and *Nectoportheus validus*). *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, p. 181.

Isolated vertebræ from Cretaceous of New Jersey.

.96 Dec. 2 Second Contribution to the History of the Vertebrata of the Miocene Period of the United States. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp. 184-194.

Two genera, thirteen species described, mainly from the Calvert formation, types mostly in Academy collection.

1869.97 Synopsis of the *Cyprinidæ* of Pennsylvania. *Trans. Amer. Philos. Soc.* N. S. Vol. XIII, 1869, pp. 351-399, Pls. X-XIII and twenty-two figures.

Systematic arrangement of genera and species, with considerable natural history data.

.98 Supplement on Some New Species of American and African Fishes. *Trans. Amer. Philos. Soc.* N. S. Vol. XIII, 1869, pp. 400-407.
Descriptions of various species, mostly new, from North and South America and Africa.

.99 Supplementary Synopsis of the *Esoces* of Middle North America. *Trans. Amer. Philos. Soc.* N. S. Vol. XIII, 1869. pp. 407-410.
Six species differentiated.

.100 Our Own Birds. A Familiar Natural History of the Birds of the United States, by William L. Baily. Revised and edited by E. D. Cope. J. B. Lippincott Co., Phila. 12mo. (1869), pp. v-x, 11-265. Ill.

.101 Feb. On the Reptilian Orders *Pythonomorpha* and *Streptosauria. Proc. Boston Soc. Nat. Hist.* Vol. XII, 1869, pp. 250-266.

.102 Feb. 6 On the Crocodilian Genus *Perosuchus. Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, p. 203.
From New Grenada (Colombia).

.103 Feb. 6 Synopsis of the Extinct Batrachia of North America. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp. 208-221.
Brief descriptions of groups, with descriptions of new genera and species from Linton, Ohio, coal-measures and from Trias.

.104 Feb. 6 On *Agaphelus,* a Genus of Toothless Cetacea. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp. 221-227.
Based upon part of a skeleton of a whale cast ashore in 1866 on the New Jersey coast.

.105 Feb. 6 On Some Cretaceous Reptilia. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp. 233-242.
Clidastes, Adocus, additional characters of *Lælaps.*

.106 Feb. 6 On the Origin of Genera. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp. 242-300.

.107 Feb. 6 Sixth Contribution to the Herpetology of Tropical America. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp. 305-313.
Including the new genera *Loxopholes* (lizard) and *Lystris* (snake) from Colombia.

.108 Feb. 6 Observations on Some Extinct Reptiles, and on a Large Rodent, *Amblyrhiza inundata. Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, p. 313. (Index title: On Extinct Reptiles.)
Elasmosaurus orientalis, Amblyrhiza inundata, brief notes.

.109 Feb. 6 Observations on Reptiles of the Old World. Art. II. *Proc. Acad. Nat. Sci. Phila.* Vol. XX, 1868, pp. 316-323.
Including new genera *Panaspis* (lizard from Australia) and *Letheobia* (snake from Zanzibar).

.110 March Note on Disease among the fossil Reptilia of New Jersey. *Amer. Nat.* Vol. III, No. 1, 1869, p. 55.
Quotation of a letter from Cope, which, however, does not refer to pathologic but a normal condition in mosasaur jaw.

.111 April Descriptions of Some Extinct Fishes Previously Unknown. *Proc. Boston Soc. Nat. Hist.* Vol. XII, 1869, pp. 310-317.
Three species of fossil Teleosts and seven Elasmobranchs determined by fragments from Coastal Plain of eastern United States.

.112 April The Fossil Reptiles of New Jersey. *Amer. Nat.* Vol. III, No. 2, 1869, pp. 84-91, Pl. 2.
Popular description and restoration of Cretaceous types.

.113 June A New Salamander. *Amer. Nat.* Vol. III, No. 4, 1869, p. 222.
Notice of a new genus, *Thorius,* from Mexico.

.114 July New Finner Whale. *Amer. Nat.* Vol. III, No. 5, 1869, pp. 277, 278.

.115 July 20 Remarks on a New Series of Fossils from the Limestone Caves in the Southern States. *Proc. Acad. Nat. Sci. Phila.* Vol. XXI, 1869, p. 3.
Stereodectes tortus brief description; Wythe Co., Va., fauna.

.116 July 20 Remarks on *Heloderma suspectum. Proc. Acad. Nat. Sci. Phila.* Vol. XXI, 1869, p. 5. (Index title: On *Heloderma horridum*).
Exhibition of a *Heloderma horridus* from Tehuantepec.

.117 July 20 Third Contribution to the Fauna of the Miocene Period of the United States. *Proc. Acad. Nat. Sci. Phila.* Vol. XXI, 1869, pp. 6-12.
Tretosphys, Zarhachis, Eschrichtius, etc., Calvert formation of Maryland and Miocene of New Jersey.

.118 July 20 On the Cetaceans of the Western Coast of North America. By C. M. Scammon. Edited by Prof. E. D. Cope. *Proc. Acad. Nat. Sci. Phila.* Vol. XXI, 1869, pp. 13-63. Figs. 1-17, Pl. I.
Contains much new material written in by Cope. Part I (pp. 14-32)—Systematic Synopsis of the Species of the

Cetaceans of the West Coast of North America—is entirely his. Also contains descriptions of new species inserted by Cope.

.119 July 20 — Remarks on Specimens of Extinct Animals from the Island of Anguilla, West Indies. *Proc. Acad. Nat. Sci. Phila.* Vol. XXI, 1869, p. 92.

Loxomylus longidens, named, no description.

.120 July 20 — A Review of the Species of *Plethodontidæ* and *Desmognathidæ*. *Proc. Acad. Nat. Sci. Phila.* Vol. XXI, 1869, pp. 93-118.

.121 July 20 — Remarks on Extinct Reptiles from New Jersey. (Hay: Remarks on *Holops brevispinus, Ornithotarsus immanis,* and *Macrosaurus proriger.*) *Proc. Acad. Nat. Sci. Phila.* Vol. XXI, 1869, p. 123.

Holops described from an incomplete cranium and *Ornithotarsus* from parts of hind leg bones, tooth from New Jersey Cretaceous; *Macrosaurus proriger* (=*Tylosaurus*) upon fragment of muzzle (? Mus. Comp. Zool.) from Kansas Cretaceous.

.122 Aug. 20 — On *Mylodon annectens* from the Post-Tertiary Rocks of South America. *Proc. Amer. Philos. Soc.* Vol. XI, 1869, pp. 15, 16.

.123 Aug. 20 — The Cretaceous Tortoises (and on Modifications of Form in the Dinosaurian Skeleton, Indicating an Approach to the Birds). *Proc. Amer. Philos. Soc.* Vol. XI, 1869, p. 16.

Brief abstract.

.124 Aug. 20 — A New Mosasauroid Reptile. *Proc. Amer. Philos. Soc.* Vol. XI, 1869, pp. 116, 117.

Clidastes propython, Polycotylus latipinnis, Ornithotarsus immanis, brief abstracts of descriptions.

.125 Sept. (?) — On some Reptilian Remains. *Amer. Journ. Sci.* Ser. 2, Vol. XLVIII, 1869, No. 143, p. 278.

.126 Oct. — On Two New Genera of Extinct Cetacea. *Amer. Nat.* Vol. III, No. 8, 1869, pp. 444, 445. *Canad. Nat.* Ser. 2, Vol. IV, 1869, pp. 320, 321.

Abstract of paper before Amer. Assoc. Adv. Sci. Tenable descriptions of *Anoplonassa forcipata;* notices of Anguilla fossils but no names.

1870.127 Feb. 18 — Seventh Contribution to the Herpetology of Tropical America. *Proc. Amer. Philos. Soc.* Vol. XI, 1869, pp. 147-169, Pls. IX-XI.

Mostly from Mexico, two from the Island of St. Martins, Spanish West Indies, and with a list of species in Orton's collection from Pebas, Equador, on the Upper Amazon and in Sumichast's from Tehuantepec, Mexico. Three new genera: *Symphimus* and *Teleolapsis* (Mexican snakes), and *Stereocyclops* (raniformian from Brazil).

.128 Feb. 18 Synopsis of the Extinct Mammalia of the Cave Formations in the United States, with Observations on some Myriapoda found in and near the same, and on some Extinct Mammals of the Caves of Anguilla, W. I., and of Other Localities. *Proc. Amer. Philos. Soc.* Vol. XI, 1869, pp. 171-192, Pls. III-V.

List of species and descriptions of five new mammals and five new myriapods from Virginia. Extended descriptions of *Amblyrhiza* and *Hoxomylus* from Anguilla.

.129 Feb. 18 Second Addition to the History of the Fishes of the Cretaceous of the United States. *Proc. Amer. Philos. Soc.* Vol. XI, 1869, pp. 240-244.

Nine species of Teleosts and Elasmobranchs based on teeth and various fragments from Coastal Plain of eastern United States.

.130 March The Limbs of Ichthyosaurus and Plesiosaurus. *Amer. Nat.* Vol. IV, No. 1, 1870, p. 127.

Review of Gegenbaur's essay.

.131 April Synopsis of the Extinct Batrachia, Reptilia and Aves of North America. *Trans. Amer. Philos. Soc.* N. S. Vol. XIV, 1870, pp. 1-252, Pls. I-XIVa and Figs. 1-55. Separates April, 1870, contain only pp. 1-235, Pls. II-XII and Figs. 1-51. Note from Miss Brown's MSS.

.132 April Discovery of a Huge Whale in North Carolina. *Amer. Nat.* Vol. IV, No. 1, 1870, p. 128.

Mesoteras kerrianus.

.133 April 12 Remarks on the Cranium of Whales and on Certain Fossil Reptiles from the North Carolina Cretaceous. *Proc. Acad. Nat. Sci. Phila.* Vol. XXI, 1869, pp. 191, 192.

Eschrichtus polyporus described; *Hadrosaurus triops* and *Hypribena crassicauda,* based on vertebræ; *Polydectes biturgidus* upon a tooth. The second and third of supposed Cretaceous age "intrusive in Miocene beds."

.134 May On Some New and Little Known Myriapoda from the Southern Alleghenies. *Trans. Amer. Entomol. Soc.* III, 1870-1871, pp. 65-67. *Ann. & Mag. Nat. Hist.* Ser. 4, Vol. VI, 1870, pp. 425-427.

.135 May — On *Megadactylus polyzelus* of Hitchcock. *Amer. Journ. Sci.* Ser. 2, Vol. XLIX, pp. 390-392. *Ann. & Mag. Nat. Hist.* Ser. 4, Vol. V, 1870, pp. 454, 455.

.136 July — Die bis jetzt bekannten Schildkroten u. d. bei Kelheim u. Hannover neu aufgefunden altesten Arten derselben, von Dr. G. A. Maack (Review). *Amer. Journ. Sci.* Ser. 2, Vol. L, 1870, pp. 136-139.

.137 July — On *Elasmosaurus platyurus,* Cope. *Amer. Journ. Sci.* Ser. 2, Vol. L, 1870, pp. 140, 141.

.138 July — On the Hypothesis of Evolution, Physical and Metaphysical. *Lippincott's Mag.* Vol. VI, 1870, pp. 29-41; 173-180; 310-319.
The pages appeared in July, August and September.

.139 July 15 — On Some Etheostomine Perch from Tennessee and North Carolina. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 261-270.
Twenty species described (eight new).

.140 July 15 — On Some Reptilia of the Cretaceous Formation of the United States. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 271-274 and 275.
Polydectes biturgidus, Liodon oongrops and *L. validus,* described; *Taphrosaurus,* new genus.

.141 July 15 — Molar Tooth and Fragment of Skeleton. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 278.
Specimens exhibited.

.142 July 15 — Verbal Communication at Meeting of the American Philosophical Society, February 18, 1870. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 284.
Notice of new species of *Mosasaurus, M. oarthrus, M. fulciatus,* from the New Jersey Cretaceous.

.143 July 15 — Fourth Contribution to the History of the Fauna of the Miocene and Eocene Periods of the United States. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 285-294.
Cetacea; *Sus* sp. (subsequently *S. vagrans,* Cope) and *Thinotherium* gen. nov.; fishes. Types of *S. vagrans* and *Thinotherium annulatum* in American Museum of Natural History.

.144 July 15 — On Adocus, a Genus of Cretaceous Emydidæ. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 295-298.
Extended description, five species referred.

.145 July 15 — Note on Skeletons Found Near Woodbury. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 310, 311.
Probably early Europeans.

.146 July 15 Photographic Pictures of Figures of the Human Foot on Rocks. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 311.
Indian drawings.

.147 July 15 Fossil Fishes. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 316.
Exhibit of fishes from Green River shales—2 named but not described. See also No. 154.

.148 Sept. Observations on the Fauna of the Southern Alleghanies. *Amer. Nat.* Vol. IV, No. 7, 1870, pp. 392-402.
Fishes barely referred to.

.149 Sept. Additional Note on *Elasmosaurus platyurus*. *Amer. Journ. Sci.* Ser. 2, Vol. L, 1870, pp. 268, 269.

.150 Oct. On the Structural Characteristics of the Cranium in the Lower Vertebrata. *Amer. Nat.* Vol. IV, No. 8, 1870, pp. 505-508.
An abstract of 163.

.151 Nov. Reptiles of the Triassic Formation of the United States. *Amer. Nat.* Vol. IV, No. 9, 1870, pp. 562, 563.
Abstract of paper before A. A. A. S. No. 166. *Belodon lepturus* named, no description.

.152 Nov. 21 Vertebræ and other parts of a New Species of Bottosaurus. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 367.
Abstract four lines.

.153 Nov. 21 A New Dycynodont cranium from the Trias of South Africa. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 370.
Abstract of No. 156.

.154 Nov. 21 Observations on the Fishes of the Tertiary Shales of Green River, Wyoming Territory. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 380-384.
Asineops squamifrons N. G. et Sp., two species of *Clupea* and one of *Cyprinodon*.

.155 Nov. 21 Supplementary notice of a New Chimaerid from New Jersey. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 384.
Leptomylus cookii, Cope.

.156 Nov. 21 *Lystrosaurus frontosus*. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 419.
A new genus of Dicynodont reptiles from the Permian of South Africa. (Type believed to be in the collections of Yale University.)

.157 Nov. 21 On *Astracanthus Agassiz*. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 439, 440. (5 lines).
First record of this genus from the United States.

.158 On *Labidesthes* Cope. *Proc. Amer. Philos. Soc.*, Vol. XI,
Nov. 1870, p. 440. (5 lines.)
21 Verbal notes.

.159 On the Reptilia of the Triassic Formations of the Atlantic
Nov. Region of the United States. *Proc. Amer. Philos. Soc.* Vol.
21 XI, 1870, pp. 444-446. *Ann. & Mag. Nat. Hist.*, Ser. 4, Vol. VI, 1870, pp. 498-500.

Discussion of affinities of various species; *Pneumatoarthrus* described.

.160 Some Australian Skulls and a Maori Skull. *Proc. Amer.*
Nov. *Philos. Soc.* Vol. XI, 1870, p. 446.
21

.161 A Partial Synopsis of the Fishes of the Fresh Waters of
Nov. North Carolina. *Proc. Amer. Philos. Soc.* Vol. XI, 1870,
21 pp. 448-495, figs. 1, 2.

The first considerable report on the fresh-water fishes of N. C. 81 species are described. Included are descriptions of a considerable number of new as well as old species from sections reaching from Maine to Indiana.

.162 *Liodon perlatus* and *Mosasaurus brumbyi*. *Proc. Amer.*
Nov. *Philos. Soc.* Vol. XI, 1870, pp. 496-497.
21 Abstract, seven lines.

.163 On the Structure of the Crania of the Orders of Reptilia
Nov. and Batrachia. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp.
21 497, 498. *Ann. & Mag. Nat. Hist.* Ser. 4, Vol. VII, 1871, pp. 67, 68.

Recent and extinct. Notes. Ichthyopterygia and Anomodontia.

1871.164 Catalogue of Batrachia and Reptilia obtained by J. A. McNiel in Nicaragua. *Second and Third Ann. Report, Trustees, Peabody Acad. Sci.* 1869-1870, pp. 80-82.

Including a new genus of snake, *Enulius*.

.165 Catalogue of Reptilia and Batrachia obtained by C. J. Maynard in Florida. *Second and Third Ann. Report, Trustees, Peabody Acad. Sci.*, 1869-1870, pp. 82-85.

.166 On the Homologies of some of the Cranial Bones of the Reptilia and on the Systematic Arrangement of the Class. *Proc. A. A. A. S.* XIX Meet. 1870, pp. 194-246, figs. 1-24.

With a catalogue of the families of the Reptilia and a note on the stratigraphic relation of the orders.

.167 Note in Reply to Dr. Seeley's Remarks on my Interpretation of the Structure of the Cranium of *Ichthyosaurus*. *Proc. A. A. A. S.* XIX Meet. 1870, pp. 246, 247.

.168 On the Fossil Reptiles and Fishes of the Cretaceous Rocks of Kansas. Preliminary Report, U. S. Geological Survey of Wyoming, etc. (Being a Second [4th] Ann. Report of Progress), 1871, pp. 385-424.

For fishes, 5 species of *Saurocephalus,* and 1 each of *Ichthyodectes, Apsopilix* and *Sphyraena,* are described, and a tooth of *Enchodus* sp., is briefly referred to.

.169 On the Fishes of the Tertiary Shales of Green River, Wyoming Territory. Preliminary Report, U. S. Geological Survey of Wyoming, etc. (Being a Second [4th] Ann. Report of Progress), 1871, pp. 425-431.

Two species of *Asineops* are described; the genus *Erematopterus* is established and the species *E. nickseri* described; 2 genera of *Clupea* are described as is also *Osteoglossum encoastum* N. Sp.

.170 Recent Reptiles and Fishes. Report on the Reptiles and Fishes obtained by the Naturalists of the Expedition. Preliminary Report, U. S. Geological Survey of Wyoming, etc. (Being a Second [4th] Ann. Report of Progress), 1871, pp. 432-442.

Eight reptiles from Utah, Colorado and Wyoming. In fishes 1 Cottid, 2 Salmonids, 4 Catostomids, and 11 Cyprinids including 15 new species are described.

.171 New Fossil Fishes. *Amer. Nat.* Vol. IV, 1870-1871, p. 695.
Jan. *Amer. Journ. Sci.* Ser. 3, Vol. I, p. 386.

Species of *Saurocephalus* Harland and *Ichyodectes* gen. nov. are described from specimens collected by Professor B. F. Mudge in the Cretaceous of Kansas. Abstract of 175.

.172 On Siredon-Metamorphoses. *Amer. Journ. Sci.* Ser. 3, Vol.
Feb. I, 1871, pp. 89, 90. Reprint, *Ann. & Mag. Nat. Hist.* Ser. 4, Vol. VII, 1871, pp. 246, 247.

Reprinted by Dr. H. C. Yarrow in *Rept. U. S. Geol. Survey West of the* 100th *Meridian* (Wheeler), Vol. V, Chap. IV, pp. 517-519.

.173 Some Remains of a New Cretaceous Tortoise and on *Læ-*
Feb. *laps. Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 515.
17 *Adocus syntheticus* described; metatarsals of *Lælaps.*

.174 The Osteology of *Megaptera bellicosa. Proc. Amer. Philos.*
Feb. *Soc.* Vol. XI, 1870, p. 516.
17

.175 On the *Saurodontidæ. Proc. Amer. Philos. Soc.* Vol. XI,
Feb. 1870, pp. 529-538. Abstract, "New Fossil Fishes," *Amer.*
17 *Nat.* Vol. IV, 1870, p. 695; and *Amer. Journ. Sci.* Ser. 3, Vol. I, p. 386.

See 171 for note on new genera. Five species of *Saurocephalus* (three new) described, one *Saurodon* and *Ichthyodectes ctenodon* Sp. N. For preliminary account see No. 171.

.176 On the Fishes of a Fresh Water Tertiary in Idaho, dis-
Feb. covered by Capt. Clarence King. *Proc. Amer. Philos. Soc.*
17 Vol. XI, 1870, pp. 538-547.

Chiefly Cyprinid fishes of supposed Pliocene age: *Diastichus, Oligobelus, Anchybopsis, Rhabdofario,* new genera, based upon pharyngeal bones except the last.

.177 On the Adocidæ. *Proc. Amer. Philos. Soc.* Vol. XI, 1870,
Feb. pp. 547-553.
17 Additional observations upon *Adocus* Cope, with a key to the species; *Zygoramma, Homorophus,* new genera of Adocidæ, based upon fossils from the New Jersey Cretaceous.

.178 Eighth Contribution to the Herpetology of Tropical America.
Feb. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 553-559.
17 Report upon collections of Ophidia and Batrachia from Pebas, Ecuador (Hauxwell), Brazil (Thayer Exp.), Turk's Island, W. I. (Ebell), and St. Eustatia (van Rigjersma). *Enulius* gen. nov. ophid. from Nicaragua.

.179 Contribution to the Ichthyology of the Marañon. *Proc.*
Feb. *Amer. Philos. Soc.* Vol. XI, 1870, pp. 559-570, eight figures.
17 *Stethaprion, Holotaxis, Plethodectes, Odontostilbe,* new Characid genera described. Five new species of Siluridæ, and three new Chromidæ (Cichlidæ) described.

.180 *Mosasaurus maximus* (and *Liodon ictericus* and *L. mudgei*).
Feb. (Frazer—Note on two Species of Pythonomorpha from
17 Kansas and New Mexico.) *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 571-572.

.181 On some Species of Pythonomorpha from the Cretaceous
Feb. Beds of Kansas and New Mexico. *Proc. Amer. Philos. Soc.*
17 Vol. XI, 1870, pp. 574-584. Abstract, *Amer. Nat.* Vol. VI, 1872, p. 246.

Liodon dyspelor from New Mexico; *L. ictericus* and *mudgei;* and *Clidastes cinerarium* from Kansas.

.182 On Three Extinct Astaci from the Fresh Water Territory
Feb. of Idaho. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, pp. 605-
17 607.

Types in the Smithsonian Institution. King expedition.

.183 Note on *Saurocephalus* Harlan. *Proc. Amer. Philos. Soc.*
Feb. Vol. XI, 1870, p. 608. Abstract, *Amer. Journ. Sci.* Ser.
17 3, Vol. I, 1871, p. 386.

Discussion of affinities.

.184 Feb. 17 Fossils from West Indian Island Caves. *Proc. Amer. Philos. Soc.* Vol. XI, 1870, p. 608. Abstract, *Amer. Journ. Sci.* Ser. 3, Vol. I, p. 385.

Notice of additional collections from Anguilla, *Loxomylus latidens* described.

.185 March On the System of the Batrachian Anura of the British Museum Catalogue. *Amer. Journ. Sci.* Ser. 3, Vol. I, 1871, pp. 198-203.

.186 March Cave Mammals in Pennsylvania. *Amer. Nat.* Vol. V, 1871, p. 58.

Abstract of 196.

.187 March 14 Remarks on a Specimen of *Trigonocephalus* and *Oxyrrhopus plumbeus*. *Proc. Acad. Nat. Sci. Phila.* Vol. XXII, 1870, p. 90.

Fer-de-lance a serious pest on the islands of Martinique and Guadaloupe, might be reduced by importation of *Oxyrrhopus* which feeds on them.

.188 March 14 Observations on Some Fishes New to American Fauna found at Newport, Rhode Island, by Samuel Powell. *Proc. Acad. Nat. Sci. Phila.* Vol. XXII, 1870, pp. 118-121.

Eleven species listed and some described, including three new species mainly West Indian stragglers brought up by the Gulf Stream.

.189 March 14 Supplementary Note on Two New Fishes from the Southern Coast. *Proc. Acad. Nat. Sci. Phila.* Vol. XXII, 1870, pp. 120, 121.

Centropristis subligularius and *Gobiesax strumosus* N. Sp., from Hilton Head, S. C.

.190 March 14 Note on Fishes from Atlantic City, New Jersey. *Proc. Acad. Nat. Sci. Phila.* Vol. XXII, 1870, p. 121.

Priacanthus altus and *Hemiramphus macrorhynchus.*

.191 March 14 Remarks on Fossil Reptiles from the Cretaceous Beds of Kansas. *Proc. Acad. Nat. Sci. Phila.* Vol. XXII, 1870, p. 132.

Tenable description of *Liodon ictericus, L. mudgei, L. dyspelor, Clidastes cinerionum (sic).*

.192 May 9 Observations on *Sauropleura remex* and *Osteocephalus amphiuminus. Proc. Acad. Nat. Sci. Phila.* Vol. XXIII, 1871, p. 53.

.193 May 9 On Fishes from the Amazon River. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIII, 1871, p. 55.

Exhibit and remarks on four species found above the mouth of the Rio Negro.

.194 On some of the Siluroids of the Amazon. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIII, 1871, p. 112.
July
11
Oral remarks on certain anatomical structures as a basis for taxonomy of Silurids.

.195 On *Plectognathi* and *Lophobranchii. Proc. Acad. Nat. Sci. Phila.* Vol. XXIII, 1871, pp. 157, 158.
Aug.
15
Structure serving as basis for differentiation from other fishes and for classification in the system.

.196 The Port Kennedy Bone Cavern. *Proc. Amer. Philos. Soc.* Vol. XII, 1871, pp. 15, 16.
Aug.
18
For abstract see 186. Preliminary notice of the fauna. See. No. 200.

.197 Supplement to the "Synopsis of the Extinct Batrachia and Reptilia of North America." *Proc. Amer. Philos. Soc.* Vol. XII, 1871, pp. 41-52.
Aug.
18
Descriptions of *Liodon sectorius* n. sp., *Zygoramma microglypha* n. sp., *Catapleura ponderosa* n. sp., *Bottosaurus macrorhynchus* Harlan, *Hadrosaurus cavatus* n. sp., all from the New Jersey Cretaceous.

.198 On Two Extinct Forms of Physostomi of the Neotropical Region. *Proc. Amer. Philos. Soc.* Vol. XII, 1871. pp. 52-55.
Aug.
18
Prymnetes and *Anædopogon,* new genera.

.199 On the Occurrence of Fossil *Cobitidæ* in Idaho. *Proc. Amer. Philos. Soc.* Vol. XII, 1871, p. 55.
Aug.
18
Diastichus Cope referred to the Cobitidæ.

.200 Preliminary Report on the Vertebrata discovered in the Port Kennedy Bone Cave. *Proc. Amer. Philos. Soc.* Vol. XII, 1871, pp. 73-102, figs. 1-20.
Aug.
18
Descriptions and notices of thirty-four species of mammals, thirteen of them new, and *Praotherium,* N. Gen.

.201 On *Megaptera bellicosa. Proc. Amer. Philos. Soc.* Vol. XII, 1871, pp. 103-108, figs. 21-22.
Aug.
18
Description of skeleton from St. Bartholomew, W. I.

.202 Additional Note on *Balænoptera* vel *Sibbaldius sulfureus* Cope. *Proc. Amer. Philos. Soc.* Vol. XII, 1871, p. 108.
Aug.
18

.203 Remarks on Ancient Rock Inscriptions in Ohio. *Amer. Nat.* Vol. V, 1871, p. 546.
Sept.

.204 On the Extinct Tortoises of the Cretaceous of New Jersey. *Amer. Nat.* Vol. V, 1871, pp. 562-564. (Abstract of paper read before A. A. A. S. Exactly reprinted in *Proc. A. A. A. S.*, XX Meet., pp. 344, 345.)
Sept.

.205 Sept. Observations on the Systematic Relations of the Fishes. *Amer. Nat.* Vol. V, 1871, pp. 579-593. *Ann. & Mag. Nat. Hist.* Ser. 4, Vol. IX, 1872, pp. 155-168.
Abridged form of 211.

.206 Sept. The Laws of Organic Development. (Abstract of paper before A. A. A. S. but not printed in *Proceedings.*) *Amer. Nat.* Vol. V, 1871, pp. 593-605. *Nature,* Vol. V, 1872, pp. 252-254.

.207 Oct. 24 Ninth Contribution to the Herpetology of Tropical America. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIII, 1871, pp. 200-204.
From the Isthmus of Darien, Isthmus of Tehuantepec, eastern Ecuador, southeastern Haiti. A new snake genus, *Nothopsis* from Isthmus of Darien. Annotated synopsis of the *Teleuraspides.*

.208 Nov. Geological Expedition to Kansas. *Amer. Nat.* Vol. V, 1871, pp. 792-795.

.209 Nov. Life in the Wyandotte Cave. *Ann. & Mag. Nat. Hist.* Ser. 4, Vol. VIII, 1871, pp. 368-370. (Copied from *Indianapolis Journ.* Sept. 5, 1871.)
Amblyopsis sp., a blind fish found.

.210 Dec. Contribution to the Ichthyology of the Lesser Antilles. *Trans. Amer. Philos. Soc.* n. s. Vol. XIV, 1871, pp. 445-483; figs. 1-10.
Faunal list based on collection from St. Martins, St. Croix, and St. Kits. Included are numerous new species.

1872.211 Observations on the Systematic Relations of the Fishes. *Proc. A. A. A. S.* XX Meet. 1871, pp. 317-343.
For abstract see 205. Extensive presentation of Cope's views on the subject.

.212 On the Geology and Palæontology of the Cretaceous Strata of Kansas. *Preliminary Report, U. S. Geol. Survey of Montana,* etc. Being a Fifth Annual Report of Progress, Part III, pp. 318-349.
Reprinted, with slight changes, by W. E. Webb, in "Buffalo Land: An Authentic Account of the Discoveries, Adventures, and Mishaps of a Scientific and Sporting Party in the Wild West . . ." 8vo. Hubbard Bros., Philadelphia, 1872 (pp. 338-365). Extended description of vertebrate fauna of Niobrara formation, many new species.

.213 On the Vertebrate Fossils of the Wahsatch Strata. *Preliminary Report, U. S. Geol. Survey of Montana,* etc. Being a Fifth Annual Report of Progress, Part III, pp. 350-353.

Redescription of *Bathmodon, Loxolophodon* described. Compare No. 266. This report is reviewed in *Amer. Journ. Sci.* (3) III, May, 1872, and must therefore have been published in May or earlier.

.214 Report on the Recent Reptiles and Fishes of the Survey, collected by Campbell Carrington and C. M. Dawes. *Preliminary Report, U. S. Geol. Survey of Montana,* etc. Being a Fifth Annual Report of Progress, Part IV, pp. 467-476.

Twenty species described, 15 being new.

.215 Sketch of the Zoology of Pennsylvania. *Walling and Gray's Topographical Atlas of Pennsylvania,* pp. 19-22.

.216 Carboniferous Reptiles of Ohio. *Amer. Nat.* Vol. VI, 1872,
Jan. p. 46.

Abstract of 220.

.217 On the Fishes of the Ambyiacu River. *Proc. Acad. Nat.*
Jan. *Sci. Phila.* Vol. XXIII, 1871, pp. 250-294, Pls. III-XVII.
16 Comprises an extensive collection from Pebas, referable to 50 genera and 76 species, mostly Chromids (Cichlids), Characins, and Silurids. Nine genera and 47 species are new to science with one exception belonging to the above.

.218 Note on some Cretaceous Vertebrata in the State Agricul-
Feb. tural College of Kansas, U. S. A. *Proc. Amer. Philos. Soc.*
2 Vol. XII, 1871, pp. 168-170.

Anogmius gen. nov. and *Liodon latispinis* sp. nov. described.

.219 Sketch of an Expedition in the Valley of the Smoky Hill
Feb. River in Kansas. *Proc. Amer. Philos. Soc.* Vol. XII, 1871,
2 pp. 174-176.

.220 Observations on the Extinct Batrachian Fauna of the Car-
Feb. boniferous of Linton, Ohio. *Proc. Amer. Philos. Soc.* Vol.
2 XII, 1871, p. 177.

List of genera with brief diagnosis of characters. *Tuditanus, Cocytinus, Phlegcthontia* are new. For abstract see 216.

.221 Remarks on Hyrtl's Collection. *Proc. Amer. Philos. Soc.*
Feb. Vol. XII, 1871, p. 191.
2

.222 Observations on the Distribution of certain Extinct Verte-
Feb. brata in North Carolina. *Proc. Amer. Philos. Soc.* Vol.
2 XII, 1871, pp. 210-216, Pls. I-IV.

Chiefly Triassic and Cretaceous fossils. *Hypsibema* gen. nov. and *Hadrosaurus tripos* sp. nov. are based upon skeleton fragments of Trachodont dinosaurs.

.223 Feb. 2 The Method of Creation of Organic Forms. *Proc. Amer. Philos. Soc.* Vol. XII, 1871, pp. 229-263.

.224 Feb. 13 On a Species of Galeodes. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIII, 1871, p. 295.

.225 Feb. 13 On the Fauna of the Wyandotte Cave in Southern Indiana. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIII, 1871, p. 297.
Amblyopsis spelaeus, the only fish found.

.226 Feb. 13 On some Fossil Reptiles from the Cretaceous Chalk of Western Kansas. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIII, 1871, pp. 297, 298.
Preliminary notice, names but no adequate descriptions of four new species of Mosasaurs.

.227 Feb. 13 On a peculiar Habit in *Phrynosoma. Proc. Acad. Nat. Sci. Phila.* Vol. XXIII, 1871, p. 305.
P. ornatissima Grd. Squirting blood from the eyes.

.228 March 7 The Survival of the Fittest. *Nature,* Vol. V, 1872, p. 363.

.229 April On a New Fossil Reptile from the Cretaceous Strata of Kansas. *Amer. Nat.* Vol. VI, 1872, p. 247.
Abstract of 263.

.230 April Families of Fossil Fishes of the Cretaceous of Kansas. *Amer. Nat.* Vol. VI, 1872, pp. 249, 250.
Abstract of 265.

.231 April On *Protostega. Amer. Nat.* Vol. VI, 1872, p. 251.
Abstract of 268.

.232 April On Two New Species of *Ornithosaurians* from the Kansas Cretaceous. *Amer. Nat.* Vol. VI, 1872, p. 251.
Abstract of 267.

.233 April Remarks on Mr. Price's "Phases of Modern Philosophy" (Abstract). *Amer. Nat.* Vol. VI, 1872, pp. 251, 252.
Abstract of 264.

.234 April Description of the Common Lizard of Socorro. *Proc. Boston Soc. Nat. Hist.* Vol. XIV, 1871, p. 303.
Uta auriculata.

.235 April 16 On *Megaptera bellicosa. Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, p. 11.

.236 April 16 On *Holops pneumaticus. Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, pp. 11, 12.

.237 April 16 List of the Reptilia of the Eocene Formations of New Jersey. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, pp. 14-18.

Two new species of Chelonia described and one new crocodilian.

.238 May–Sept. Evolution and its Consequences. *Penn Monthly* Vol. III, 1872, pp. 222-236; 366-385; 429-439; 461-476.

The instalments appeared in May, July, August and September, respectively.

.239 May Curious Habit of a Snake. *Amer. Nat.* Vol. VI, 1872, p. 309. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, p. 40.

Oryclophis æstivus from North Carolina.

.240 June 8 Remarks on Discoveries recently made by Prof. O. C. Marsh. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, pp. 140, 141.

Separates, June 8, 1872. Date taken from Miss Brown's MSS. Critical review of Marsh's contributions on Mosasaurs.

.241 June 25 Synopsis of the Species of the Chelydrinæ. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, pp. 22-29.

.242 June 25 On an Extinct Whale from California. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, pp. 29, 30.

Eschrichtius davidsonii.

.243 June 25 On *Bathmodon radians. Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, p. 38.

Preliminary description.

.244 June 25 Intelligence in Monkeys. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, pp. 40, 41. Abstract, *Amer. Nat.* Vol. VI, 1872, pp. 371, 372.

.245 July Report on the Wyandotte Cave and its Fauna. *Amer. Nat.* Vol. VI, 1872, pp. 406-422, figs. 109-116. *Third and Fourth Ann. Rept. Geol. Survey Indiana,* 1871-1872, pp. 157-182, figs. 109-116. *Nature,* Vol. VII, 1872, pp. 11-14, figs. 1-8. Abstract, "Observations on Wyandotte Cave and its Fauna," *Eighth, Ninth and Tenth Ann. Rept. Geol. Survey Indiana,* 1876-77-78, pp. 489-506, figs. 109-116.

Includes descriptions of species from the Mammoth Cave. *Ambylopsis spelaeus* the only fish.

.246 July The Anæsthetic School. *Amer. Nat.* Vol. VI, 1872, pp. 431, 432.

Abstract of 259.

.247 A New Genus of Ungulates. *Amer. Nat.* Vol. VI, 1872,
July p. 438.
Abstract of 266.

.248 Food of *Plesiosaurus*. *Amer. Nat.* Vol. VI, 1872, p. 439.
July Abstract of 260.

.249 On a new Genus of *Pleurodira* from the Eocene of Wyo-
July ming. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 472-477
11 *Notomorpha* gen. nov., 3 species, and "*Notharctus*" *vasacciensis* (=*Eohippus*). For date see *Pal. Bull.*, No. 12, p. 3.

.250 Descriptions of Some New Vertebrata from the Bridger
July Group of the Eocene. *Proc. Amer. Philos. Soc.* Vol. XII,
29 1872, pp. 460-465. *Pal. Bull.* No. 1, pp. 1-6.

This bulletin includes first descriptions of *Mesonyx* and several new *Chelonia*.

This is the first of a series of notices describing new genera and species of fossil vertebrates discovered by Professor Cope or his assistants during his expeditions for the Hayden Survey in 1872 and 1873. The descriptions were written in the field and forwarded by mail (in two instances by telegraph) to Philadelphia for immediate publication. They are in large part transcripts from his field notebooks which are preserved in the files of the American Museum.

Their purpose was in part to anticipate the work of Professor Marsh, who was known to be studying fossil faunas of the same regions, and between whom and Cope there was a growing rivalry. They precipitated a bitter controversy, turning mainly on the correctness of the stated dates of publication. Professor Cope, in reply to Marsh's claim that the papers were seriously antedated published sworn statements from the printers that the papers were printed and delivered as dated, and somewhat less conclusive evidence as to the distribution of the separata to scientific institutions or individuals within a few days of the stated dates.

Although Professor Marsh failed to retract his charges, it is clear from this evidence, coupled with the internal evidence afforded by close study of the papers, comparison with field notebooks and other considerations that the bulletins were printed and, in most cases if not all, some copies were distributed approximately at the printed dates of publication. Any intentional antedating is out of the question. Under the circumstances it appears wholly proper to accept the accuracy of the dating.

W. D. M.

.251 Aug. The Life of the Plains. *Southern Mag.* N. S. Vol. IV, 1872, pp. 146-155.

.252 Aug. 3 Second Account of New Vertebrata from the Bridger Eocene. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 466-468. *Pal. Bull.* No. 2, pp. 1-3.

First descriptions of *Helotherium* (=*Orohippus* Marsh of identical date), *Stypolophus* (=*Sinopa* Leidy), *Pantolestes, Pseudotomus* (here referred to Edentata but in fact a rodent allied to *Paramys* Leidy) *Hadrianus* (earliest land tortoise).

.253 Aug. 7 Third Account of New Vertebrata from the Bridger Eocene of Wyoming Territory. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 469-472. As "Third Account of New Vertebrata from the Bridger Eocene of Wyoming Valley," *Pal. Bull.* No. 3, pp. 1-4.

First descriptions of *Miacis, Tomitherium* (=*Northarctus* Leidy), etc.

.254 Aug. 12 On the Existence of Dinosauria in the Transition Beds of Wyoming. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 481-483. *Pal. Bull.* No. 4, pp 1, 2.

First description of *Agathaumas*.

.255 Aug. 19 Telegram Describing Extinct Proboscidians found in Wyoming. *Pal. Bull.* No. 5.

"Lefalophodon," (intended for *Loxolophodon*) with three species, also badly misspelled. The telegram was evidently sent upon discovery of the fine skull which is the type of *Eobasileus cornutus* by Professor Cope at Haystack Mountain in the Washakie basin. It is the first published announcement of his Dinocerata discoveries, but they are here *referred to* the genus *Loxolophodon* based upon a Coryphodont from the Lower Eocene. With conjectural corrections of specific names. See 286.

.256 Aug. 20 Notices of New Vertebrata from the Upper Waters of Bitter Creek, Wyoming Territory. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 483-486. *Pal. Bull.* No. 6, pp. 1-4. Abstract, "The Proboscidians of the American Eocene" *Amer. Nat.* Vol. VI, 1872, pp. 773, 774.

First description of *Synoplotherium* and *Eobasileus*. The relationship of the former to *Mesonyx* was not yet recognized; it was thought to be allied to *Anchippodus (Tillodontia)*, the enlarged canine being mistaken for an incisor.

The new genus *Eobasileus* is here based upon the species *cornutus* with a number of fragmentary specimens as types, not including the fine skull which is the type in the telegram

from Black Buttes, written later than this notice but published earlier (see No. 255). Errors of transmission in the telegram being corrected, and the stated dates of publication being accepted, the type specimen of *cornutus* is the complete skull and the monotypic genus *Eobasileus* rests upon this species. It may be remarked incidentally that neither the original type of *Tinoceras* Marsh nor the skull subsequently used by him as a neotype of the genus is congeneric with *Eobasileus*.

.257 Aug. 22 Second Notice of Extinct Vertebrates from Bitter Creek, Wyoming. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 487, 488. *Pal. Bull.* No. 7, pp. 1, 2.

Chiefly an extended account of the discoveries noticed in the telegram from Black Buttes, published a few days earlier.

.258 Sept. 3 On the Horns of *Cariacus virginianus*. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, p. 124.

.259 Sept. 3 On different Schools of Naturalists. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, pp. 124, 125.

See 246 for abstract.

.260 Sept. 3 Description of *Plesiosaurus gulo* and the Turtle afterwards named *Toxochelys latiremis*. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, pp. 127-129.

See 248 for abstract.

.261 Sept. 3 Remarks on *Mastodon* from New Mexico. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, p. 142.

.262 Sept. 30 Catalogue of the Pythonomorpha found in the Cretaceous Strata of Kansas. *Proc. Amer. Philos. Soc.* Vol. XII, 1871, pp. 264-287.

Descriptions of several characteristic species of Mosasaurs from the Kansas chalk: *Edestosaurus* (=*Clidastes*) *tortor* and *stenops*, *Holcodus* (=*Platecarpus*) *coryphaeus*, *Liodon* (=*Tylosaurus*) *proriger* and *dyspelor*, etc. The first page only appeared in the previous number of the Proc.

.263 Sept. 30 On a New Testudinate from the Chalk of Kansas. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 308-310.

Description of *Cynocercus incisus* gen. et sp. nov. (based on caudal vertebræ, ? *Toxochelys*) and of *Hyposaurus vebbii*, crocodilian, the latter from the Benton shales. For abstract, see 229.

.264 Sept. 30 — Remarks on Mr. Price's "Phases of Modern Philosophy." *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 316-320.
For abstract, see 233.

.265 Sept. 30 — On the Families of Fishes of the Cretaceous Formation of Kansas. *Proc. Amer Philos. Soc.* Vol. XII, 1872, pp. 327-357.
Revision of the genera and species with descriptions of sixteen species. For abstract, see 230.

.266 Sept. 30 — On *Bathmodon,* an Extinct Genus of Ungulates. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 417-420.
First description of *Coryphodon* remains from the Evanston (Wyoming) Wasatch. Referred here to the Perissodactyla. The material studied included upper teeth and various fragments of the skeleton, but no lower molars, and the affinity to the European genus *Coryphodon* Owen, then known chiefly from the lower teeth, was naturally not recognized. The name *Loxolophodon,* subsequently used for a genus of *Unitatheriidæ,* was here first proposed tentatively for *B. semicinctus,* a second species of *Bathmodon,* in case it should prove generically distinct. For abstract, see 247. The paper was read Feb. 16, 1872. In case the date of publication is really as late as September the genera *Bathmodon* and *Loxolophodon* will date from No. 213.

.267 Sept. 30 — On Two New Ornithosaurians from Kansas. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 420-422.
The Kansas pterodactyles are recognized as belonging to the genus *Ornithocheirus* Seeley, typically from the English chalk and greensand. Two new species *O. umbrosus* and *harpyia* described. For abstract, see 232.

.268 Sept. 30 — A Description of the Genus *Protostega,* a form of Extinct Testudinata. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 422-433.
First description of the gigantic marine Cretaceous turtle *Protostega* based on remains from the Kansas chalk now in the American Museum collections. *Atlantochelys* and *Pneumatarthus* referred to the same group. For abstract, see 231.

.269 Oct. — The Peculiar Coloration of Fishes. *Amer. Nat.* Vol. VI, 1872, p. 637.
Color changes due to contraction and expansion of chromatophores.

.270 Oct. 12 — On a New Vertebrate Genus from the northern part of the Tertiary Basin of Green River. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, p. 554. *Pal. Bull.* No. 8, p. 1.

Anaptomorphus aemulus. First record of a recognized primate from the North American Eocene.

271 Oct. 12 Descriptions of New Extinct Reptiles from the Upper Green River Eocene Basin, Wyoming. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, pp. 554, 555. *Pal. Bull.* No. 9, p. 1.

Three new species described: *Crocodilus subulatus* and *sulciferus, Anostira radulina.*

.272 Nov. The Geological Age of the Coal of Wyoming. (Read before A. A. A. S.) *Amer. Nat.* Vol. VI, 1872, pp. 669-671.

273 Nov. Absence of Eyes in Classification. *Amer. Nat.* Vol. VI, 1872, pp. 691, 692.

.274 Nov. The Eocene Genus *Synoplotherium.* (Read before A. A. A. S.) *Amer. Nat.* Vol. VI, 1872, p. 695.

.275 Dec. The Armed Metalophodon. *Amer. Nat.* Vol. VI, 1872, pp. 774, 775.

Abstract of 285.

.276 Dec. The Fish Beds of Osino, Nevada. *Amer. Nat.* Vol. VI, December 1872, p. 775.

Abstract of 284.

277 Dec. 19 On the Geology of Wyoming. *Proc. Acad. Nat. Sci. Phila.* Vol. XXIV, 1872, pp. 279, 280. *Pal. Bull.* No. 10, pp. 1, 2.

1873.278 On the Extinct Vertebrata of the Eocene of Wyoming observed by the Expedition of 1872, with notes on the Geology. *Sixth Ann. Report, U. S. Geol. Survey of the Territories embracing . . . Montana,* etc. (Hayden) pp. 545-649, Pls. I-VI.

.279 Sketch of the Zoology of Ohio. *Walling and Gray's New Topographical Atlas of Ohio,* pp. 25-27.

280 Sketch of the Zoology of Maryland. *Walling and Gray's New Topographical Atlas of Maryland,* pp. 16-18.

.281 Jan. Proboscidians of the American Eocene. Correction. *Amer. Nat.* Vol. VII, 1873, p. 49.

Correction regarding the teeth of *Eobasileus cornutus*—Hay.

.282 Jan. 31 On Two New Perissodactyles from the Bridger Eocene. *Pal. Bull.* No. 11, pp. 1, 2.

Two species of *Palaeosyopinæ.* An extended form of an article of the same title appearing in *Proc. Amer. Philos. Soc.* Vol. XIII, pp. 35, 36.

.283 The Slaughter of the Buffalo. *Amer. Nat.* Vol. VII, 1873,
Feb. pp. 113, 114.

.284 On the Tertiary Coal and Fossils of Osino, Nevada. *Proc.*
Feb. *Amer. Philos. Soc.* Vol. XII, 1872, pp. 478-481.
7 For abstract, see 276. *Trichophanes hians* and *Amyzon mentoli* new genera and species.

.285 On the Dentition of *Metalophodon*. *Proc. Amer. Philos.*
Feb. *Soc.* Vol. XII, 1872, pp. 542-545.
7 For abstract, see 275. Description of *Metalophodon armatus* and *Alligator heterodon* from Black Buttes Eocene.

.286 Notice of Proboscidians from the Eocene of Southern Wyo-
Feb. ming. *Proc. Amer. Philos. Soc.* Vol. XII, 1872, p. 580.
7 Followed by note of the secretary correcting errors in the original which was issued as Pal. Bull. No. 5 (See, 1872 .255). Corrected version of telegram describing *Loxolophodon.*

.287 On an Extinct Genus of Saurodont Fishes from the Nio-
Feb. brara Cretaceous of Kansas. *Proc. Acad. Nat. Sci. Phila.*
11 Vol. XXIV, 1872, pp. 280, 281.
Erisichthe close to *Ichthyodectes* and *Portheus.*

.288 Note on the Cretaceous of Wyoming. *Amer. Journ. Sci.*
March Ser. 3, Vol. V, 1873, pp. 230, 231.
Slip from the "Proc. Philos. Soc., Philadelphia," published on Feb. 7. Followed by remarks by "Eds." The original not found in the Proc. Amer. Philos. Soc.—Hay.

.289 The Gigantic Mammals of the Genus *Eobasileus*. *Amer.*
March *Nat.* Vol. VII, 1873, pp. 157-160. Read before A. A. A. S.

.290 The Spike-horned Muledeer. *Amer. Nat.* Vol. VII, 1873,
March pp. 169, 170.

.291 The *Eobasileus* again. *Amer. Nat.* Vol. VII, 1873, p. 180.
March

.292 On *Toxochelys latiremis*. *Proc. Acad. Nat. Sci. Phila.* Vol.
March XXV, 1873, p. 10.
4 No description.

.293 On the Structure and Systematic Position of the Genus
March *Eobasileus* Cope. *Proc. Acad. Nat. Sci. Phila.* Vol. XXV,
4 1873, pp. 10-12.
Discussion of ordinal characters and relationships of Proboscidea.

.294 On some Eocene Mammals obtained by Hayden's Geological
March Survey of 1872. *Pal. Bull.* No. 12, pp. 1-6.
8 Partial annotated list of species from the Bridger Basin with description of *Oligstomus* gen. nov. and five new species of mammalia. Issued privately March 8, not reprinted—Hay.

.295 Dawson on Evolution. *Independent* Vol. XXV, 1873, p.
March 328.
13

.296 On the Short Footed Ungulata of the Eocene of Wyoming.
March *Proc. Amer. Philos. Soc.* Vol. XIII, 1873, pp. 38-74, Pls.
14 1-4. Extract, Journ. de Zoologie, Vol. II, 1873, pp. 168-184, Pl. VII, followed by remarks by Paul Gervais (Hay).
Revision of the Uintatheriidæ and Coryphodontidæ. Dates of earlier notices descriptive of Eocene vertebrata. Separate March 14, 1873. Date taken from Miss Brown's MSS.

.297 On *Eobasiliidæ* and *Bathmodontidæ*. *Proc. Acad. Nat. Sci.*
March *Phila.* Vol. XXV, 1873, pp. 102, 103.
25 Key to genera.

.298 A New Theory of the Origin of Species (Review). *Amer.*
April *Nat.* Vol. VII, 1873, pp. 231, 232.

.299 On some of Prof. Marsh's Criticisms. *Amer. Nat.* Vol.
April VII, 1873, pp. 290-299, Pls. 4, 5.
For extended form, see 306.

.300 Aztec Design. *Independent* Vol. XXV, 1873, p. 454.
April
10

.301 On a Skull of *Sus scropha*. *Proc. Acad. Nat. Sci. Phila.*
April Vol. XXV, 1873, p. 207.
29 Supposed fossil from North Carolina.

.302 On an Anourous Batrachian from the Eocene of Wyoming.
April *Proc. Acad. Nat. Sci. Phila.* Vol. XXV, 1873, p. 207.
29 From Green River shale. Notice.
No name or description.

.303 On the Tusk of *Loxolophodon cornutus*. *Amer. Nat.* Vol.
May VII, 1873, p. 315.

.304 On the Primitive Types of the Orders of Mammalia *Educa-*
May *bilia.* Read before the Amer. Philos. Soc., April 18, 1873,
6 printed and then withdrawn on June 20, 1873. A few separates still in existence. Separate May 6, 1873.
Discussion of the broader affinities of the Eocene mammals, especially those recently discovered in the Bridger Basin.

.305 June 5 Memory and Reminiscence in Animals. *Independent* Vol. XXV, 1873, p. 710.

.306 July On some of Prof. Marsh's Criticisms. *Pal. Bull.* No. 13, pp. 1-8.
A slightly extended form of 299.

.307 July On Prof. Marsh's Criticism. *Amer. Nat.* Appendix to July p. i (8 lines only.)

.308 July 8 Extinct Turtles from the Eocene Strata of Wyoming. *Proc. Acad. Nat. Sci. Phila.* Vol. XXV, 1873, pp. 277-279.
Trionyx heteroglyptus and *Plastomenus thomasi* from Bridger formation.

.309 July 16 Palaeontological Bulletin—Preliminary. 2 pp. (Gives titles and dates of Palaeontological Bulletins 1-13.)

.310 July 24 A Contribution to the Ichthyology of Alaska. *Proc. Amer. Philos. Soc.* Vol. XIII, 1873, pp. 24-32.
Fourteen species described, eleven new.

.311 July 24 On the Flat-Clawed Carnivora of the Eocene of Wyoming. *Proc. Amer. Philos. Soc.* Vol. XIII, 1873, pp. 198-209.
Description of *Mesonyx* and *Synoplotherium* and discussion of their affinities.

.312 July 24 On the Osteology of the Extinct Tapiroid *Hyrachyus*. *Proc. Amer. Philos. Soc.* Vol. XIII, 1873, pp. 212-224.
Description of the complete skelton of *Hyrachyus* found by Professor Cope in the Bridger Basin in 1872.

.313 July 25 On some New Extinct Mammalia from the Tertiary of the Plains. *Pal. Bull.* No. 14, pp. 1, 2.
First bulletin descriptive of discoveries made by Professor Cope in the Tertiary (Oligocene and Miocene) of northeastern Colorado in 1873. Like the preceding series these were apparently sent in from the field and are in considerable part transcripts from his field notebooks. Describes *Aelurodon* (=*Martes*) *mustelinus* and *Aceratherium* (=*Aphelops*) *megalodus*, both from the Miocene (Pawnee Creek beds) near Pawnee Buttes.

.314 Aug. On a Habit of a Species of *Blarina*. *Amer. Nat.* Vol. VII, 1873, pp. 490, 491.

.315 Aug. The Monster of Mammoth Buttes. *Penn Monthly*, Vol. IV, 1873, pp. 521-534, Plate.

.316 Aug. 20 Second Notice of Extinct Vertebrata from the Tertiary of the Plains. *Pal. Bull.* No. 15, pp. 1-6.
Describes various Oligocene (White River) fossils from northeastern Colorado. *Colotaxis* gen. nov. (=*Ischyromys*), *Symborodon* and *Miobasileus* Titanotheriidæ, *Peltosaurus* and four species of *Testudo*.

317 Aug. 20 Third Notice of Extinct Vertebrata from the Tertiary of the Plains. *Pal. Bull.* No. 16, pp. 1-8.
Describes Oligocene (White River) mammals, chiefly Insectivora and Rodents. Nine new genera.

.318 Sept. 30 On Two New Species of Saurodontidæ *Proc. Acad. Nat. Sci. Phila.* Vol. XXV, 1873, pp. 337-339.
Portheus lestrio and *P. gladius* described and *Daptinus* N. Gen. established.

.319 Sept. 30 On some New Batrachia and Fishes from the Coal Measures of Linton, Ohio. *Proc. Acad. Nat. Sci. Phila.* Vol. XXV, 1873, pp. 340-343.
Three species of *Conchiopsis* and one of *Peplorhina*.

.320 Oct. 16 Synopsis of New Vertebrata from the Tertiary of Colorado obtained during the summer of 1873. Pp. 1-19. Govt. Printing Office.
On the title page this paper is said to be extracted from the Seventh Annual Report of the U. S. Geological Survey of the Territories, but it does not appear in that volume.—Hay.

.321 Oct. 25 Fourth Notice of Extinct Vertebrata from the Bridger and the Green River Tertiary. *Pal. Bull.* No. 17, pp. 1-4.
Achænodon and *Phenacodus*, new genera.

.322 Oct. 30 Some remarkable and gigantic Animals. *Independent* Vol. XXV, 1873, p. 1351.
Unsigned. Cited by Frazer.

1874.323 Report on the Vertebrate Palaeontology of Colorado. *Seventh Ann. Report, U. S. Geol. and Geogr. Survey of the Territories* (embracing Colorado), pp. 427-533, Pls. I-VIII. Abstract, *Journ. de Zoologie* Vol. IV, 1875, pp. 354-359.
One species described; *Rhineastis, Amyzon, Clupea.*

.324 Notes on the Eocene and Pliocene Lacustrine Formations of New Mexico, including Descriptions of certain New Species of Vertebrates. *Ann. Report of the Chief of Engineers for* 1874 Vol. II, Pt. II, Appendix FF3 of Appendix FF, pp. 115-130.
For the original title and first date of issue see 358.

.325 On some Extinct Types of Horned Perissodactyles. *Proc. A. A. A. S.* XXII Meeting, 1873, pp. 108, 109. *Canadian Naturalist* Vol. VII, pp. 169-171. *Ann. & Mag. Nat. Hist.* Ser. 4, Vol. XIII, 1874, pp. 405, 406.

.326 The Doctrine of the Inner Light. *The Journal* (Published for Ye Society of Friends), 1874, pp. 1-7.

.327 Jan. 13 On Stone Circles in the Rocky Mountains. *Proc. Acad. Nat. Sci. Phila.* Vol. XXV, 1873, p. 370.

.328 Jan. 13 On the Types of Molar Teeth. *Proc. Acad. Nat. Sci. Phila.* Vol. XXV, 1873, p. 371.
Outline of No. 335.

.329 Jan. 21 Report on the Stratigraphy and Pliocene Vertebrate Palaeontology of Northern Colorado. *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. 1, No. 1, pp. 9-22.

.330 Jan. 21 Supplementary additions to the "Synopsis of New Vertebrata from the Tertiary of Colorado, 1873." *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. I, No. 1, pp. 22-28.

.331 Feb. Monkeys in the American Miocene. *Amer. Nat.* Vol. VIII, 1874, pp. 125, 126.
Menotherium lemurinum; no description. Skeleton of *Protohippus sejunctus.*

.332 Feb. The Succession of Life in North America. *Penn Monthly* Vol. V, 1874, pp. 138-145. Reprint, *Ann. & Mag. Nat. Hist.* Ser. 4, Vol. XIII, 1874, pp. 326-331.

.333 Feb. 17 On Fishes from the Coal Measures of Linton, Ohio. *Proc. Acad. Nat. Sci. Phila.* Vol. XXV, 1873, pp. 417-419.
Conchiopsis and *Peplorhina* are fishes not amphibians or reptiles as thought by Newberry.

.334 Feb. 17 On Fossils from the Miocene Formations of Colorado. *Proc. Acad. Nat. Sci. Phila.* Vol. XXV, 1873, pp. 419, 420.
Menotherium lemurinum a primate. Notice of other species from Pawnee Buttes. No adequate description.

.335 March 30 On the Homologies and Origin of the Types of Molar Teeth of Mammalia *Educabilia. Journ. Acad. Nat. Sci. Phila.* Ser. 2, Vol. VIII, 1874, pp. 71-89, figs. 1-29.
Abstract, No. 328. Separates March 30, 1874.

.336 April 9 Review of the Vertebrata of the Cretaceous Period found West of Mississippi River. Section I—On the Mutual Relations of the Cretaceous and Tertiary Formations of the West.

Section II—List of Species of Vertebrata from the Cretaceous Formations of the West. *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. I, No. 2, pp. 5-48.

.337 April 9 Supplementary Notices of Fishes from the Freshwater Tertiaries of the Rocky Mountains. *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. I, No. 2, pp. 49-51.

Rhineastis pectinatus, Amyzon commune and *Clupea theta* new species.

338 April 13 On the *Plagopterinæ* and the Ichthyology of Utah. *Proc. Amer. Philos. Soc.* Vol. XIV, 1874, pp. 129-139.

Reprint April 13, 1874—date from Miss Brown's MSS. *Plagopterus, Meda,* and *Lipomeda,* new fossil genera with 3 species. Twelve freshwater fishes (5 new species) from Lake Utah. Eight species (5 new) from streams in Utah and Arizona.

.339 April 13 On the Zoology of a Temporary Pool on the Plains of Colorado. *Proc. Amer. Philos. Soc.* Vol. XIV, 1874, pp. 139, 140.

Reprints April 13, 1874—date from Miss Brown's MSS.

.340 April 28 On the Extinct Fauna of Colorado. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874, pp. 10, 11.

Discussion by Cope, LeConte and Frazer on age of "lignite" beds of N. E. Colorado.

.341 April 28 On the Age of the Lignites of the West. (Observations on the age of lignite and other formations of the West—Hay). *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874, pp. 10-13.

.342 May Beale on Protoplasm (Review of *Protoplasm, or Matter and Life* by Dr. Lionel Beale). *Penn Monthly* Vol. V, 1874, pp. 377-388.

.343 May 19 Description of some Species of Reptiles obtained by Dr. John F. Bransford, Assistant Surgeon United States Navy, while attached to the Nicaraguan Surveying Expedition in 1873. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874, pp. 64-72.

.344 July A New Type of Snake. *Amer. Nat.* Vol. VIII, 1874, p. 432.

Genhosteus prosopis from Peru.

.345 July A Horned *Elotherium.* *Amer. Nat.* Vol. VIII, 1874, p. 437.

E. ramosum "horns" on lower jaw.

.346 Aug. 18 On a young *Balæna cisarctica.* *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874, p. 89.

.347 On the Extinct Mammalia of Colorado. (Remarks on *Sym-*
Aug. *borodon, Titanotherium,* and *Eobasileus.*—Hay). *Proc. Acad.*
18 *Nat. Sci. Phila.* Vol. XXVI, 1874, pp. 89, 90.
Notice of exhibition of *Symborodon crania.*

.348 On the Pelvis of *Hadrosaurus. Proc. Acad. Nat. Sci. Phila.*
Aug. Vol. XXVI, 1874, p. 91.
18 Critical comment on views of Hawkins and Leidy. Three lines.

.349 On the Genus *Ctenodus. Proc. Acad. Nat. Sci. Phila.* Vol.
Aug. XXVI, 1874, pp. 91, 92.
18 Description of bones of head—no species assigned.

.350 Remarks on Viviparous Snakes of the Genus *Storeria* B. &
Sept. G. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874, p. 116.
29 First notice of the genus as viviparous.

.351 On the Age of the Bridger Eocene. *Proc. Acad. Nat. Sci.*
Sept. *Phila.* Vol. XXVI, 1874, p. 116.
29 Middle Eocene, older than Parisian.

.352 On the Palæontology of Colorado. (Synopsis of result of
Sept. work in connection with Hayden's U. S. Geological Survey
29 during 1873.—Hay). *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874, pp. 116, 117.

.353 On some Batrachia and Nematognathi brought from the
Sept. Upper Amazon by Professor Orton. *Proc. Acad. Nat. Sci.*
29 *Phila.* Vol XXVI, 1874, pp. 120-137.
Describing two new batrachian genera, *Bubonias* and *Dysichthys.* Seventeen Nematognathi listed, seven described as new.

.354 Remarks on *Brontotherium.* (Remarks of Professor Marsh's
Oct. *Brontotherium ingens.*—Hay). *Proc. Amer. Philos. Soc.*
2 Vol. XIV, 1874, p. 2.
Synonym of *Symborodon trigonoceras.*

.355 Remarks on *Eobasileus galeatus* and on a Fossil Walrus.
Oct. *Proc. Amer. Philos. Soc.* Vol. XIV, 1874, pp. 17, 18.
2 Exhibition of fragmentary skull and of walrus skull from Accomac, Va.

.356 Abstract of Remarks of Professor Cope at the Meeting of
Oct. the American Philosophical Society, January 16, 1874. *Proc.*
2 *Amer. Philos. Soc.* Vol. XIV, 1874, p. 110.
Poëbrotherium, an ancestor of the Camelidæ.

.357 Notes on the Santa Fé Marls, and some of the contained
Oct. Vertebrate Fossils. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI,
20 1874, pp. 147-152. *Pal. Bull.* No. 18, pp. 147-152.
Six new species described: *Panolax* new genus.

.358 Nov. 28 Report upon the Vertebrate Fossils discovered in New Mexico with Descriptions of New Species. Note from Miss Brown's MSS. Issued as a separate (pp. 1-18) on November 28. The same paper as 324.

.359 Dec. 15 Extract of a Letter from Nacimento, New Mexico. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874, p. 163.
Notice of archaeological discoveries.

1875.360 Supplement to the Extinct Batrachia and Reptilia of North America. I—Catalogue of the Air-breathing Vertebrata from the Coal Measures of Linton, Ohio. *Trans. Amer. Philos. Soc.* n. s. Vol. XV, 1874, pp. 261-278.

.361 The Vertebrata of the Cretaceous Formations of the West. *Report, U. S. Geological Survey of the Territories* (Hayden) Vol. II, pp. 1-303, Pls. I-LVII and figs. 1-10 (4to.).
For a slightly changed form of pp. 7-14, see 375.

.362 On the Fishes of the Tertiary Shales of the South Park. *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. II, No. 1, pp. 3-5.

.363 Report on the Geology of that Part of Northwestern New Mexico examined during the field season of 1874. *Ann. Report upon the Geogr. Explorations and Surveys West of the 100th Meridian* . . . (Wheeler). Being Appendix LL of the Annual Report, Chief of Engineers for 1875, pp. 961-1097, Pls. II, V, VI, figs. 1-18. When Appendix LL, etc. was issued as a separate the pagination was pp. 61-116.

.364 Report on the Remains of a Population observed on and near the Eocene Plateau of Northwestern New Mexico. *Ann. Report upon the Geogr. and Geol. Explorations and Surveys West of the 100th Meridian* . . . (Wheeler), pp. 166-173, figs. 1-6. (Exactly the same text as 408. The figures are lacking in the former.)

.365 [Synopsis of the Genera Crotalus and Eutaenia, together with descriptions of one New Genus and Seven New Species]. Report upon the Collections of Batrachians and Reptiles made in portions of Nevada . . . during the years, 1871, 1872, 1873, 1874 by Dr. H. C. Yarrow. *Report, U. S. Geogr. Surveys West of the 100th Meridian* . . . (Wheeler) Vol. V, Chap. IV, pp. 532-536. (Material inserted in Yarrow's Chapter.) (4to.)
New genus is *Chilopoma* (preoccupied) now a synonym of *Thamnophis.*

.366 Report upon the Collection of Fishes made in Portions of Nevada, Utah, California, Colorado, New Mexico and Arizona

during the years 1871, 1872, 1873 and 1874. (With H. C. Yarrow.) *Report, Geogr. and Geol. Explor. and Surveys West of the 100th Meridian* (Wheeler) Vol. V, Chapter VI, pp. 630-703, Pls. XXVI-XXXII (4to.).
Systematic arrangement with descriptions of all the fishes collected by all the naturalists of all the expeditions working in the states during the years named. Several new species are described.

.367 Check-List of North American Batrachia and Reptilia; with a Systematic List of the Higher Groups, and an Essay on Geographical Distribution, based on the specimens contained in the U. S. National Museum. *Bull. U. S. Nat. Museum,* No. 1, pp. 1-104.

.368 Synopsis of the Vertebrata whose Remains have been preserved in the Formations of North Carolina. *Rept. Geol. Survey, North Carolina,* W. C. Kerr, State Geologist, Appendix B., pp. 29-52, Pls. V-VIII.

.369 Synopsis of the Extinct Batrachia from the Coal Measures. *Rept. Geol. Survey Ohio* Vol. II (Palaeontology) Pt. II, pp. 349-411, Pls. XXVI-XLV, figs. 1-11.

.370 Report on the Vertebrate Fossils from the Fort Union Groups of Milk River. *Report* (of the British North American Boundary Commission), *on the Geology and Resources of the Region in the Vicinity of the 49th Parallel* (Dawson), Appendix B., pp. 333-337.

.371 New Forms of *Elasmosauridæ. Amer. Nat.* Vol. IX, 1875,
Jan. p. 55.
Review of Seeley.

.372 American Types in the Cretaceous of New Zealand. *Amer.*
Jan. *Nat.* Vol. IX, 1875, pp. 55, 56.
Review of Hector.

.373 A New Mastodon. *Amer. Nat.* Vol. IX, 1875, p. 56.
Jan. *M. productus* from Sante Fe—no description.

.374 The Wheeler Geological Survey of New Mexico for 1874.
Jan. *Amer. Nat.* Vol. IX, 1875, pp. 49-52.
Abstract report of Cope's party.

.375 The Value of Palaeontology. (The Significance of Palaeon-
Jan. tology—Cover Title.) *Penn Monthly.* Vol. VI, pp. 55-62.
A very slightly changed form of the introduction in 361.

.376 Feb. 2 On a New Mastodon and Rodent. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874, pp. 221-223. Abstracts, "A New Mastodon," *Amer. Nat.* Vol. IX, 1875, p. 56.

Description of *Mastodon productus* and *Steneofiber pansus* from Santa Fe bed of New Mexico.

.377 Feb. 2 On the Characters of *Symborodon*. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874. p. 224.

Distinction from *Titanotherium*.

.378 Feb. 2 On Dr. Leidy's "Correction". *Proc. Acad. Nat. Sci. Phila.* Vol. XXVI, 1874, pp. 224, 225.

Concerning the relationships of *Thespesius* and *Ischyrosaurus*.

.379 March Note on the Genus *Calamodon*. *Amer. Journ. Sci.* Ser. 3, Vol. IX, 1875, pp. 228, 229.

.380 March Biological Research in the United States. *Penn Monthly*, Vol. VI, 1875, pp. 202-211.

.381 April 17 Systematic Catalogue of Vetebrata of the Eocene of New Mexico collected in 1874. *Report, Engineer Department, U. S. Army* in charge of Lieut. Geo. M. Wheeler, pp. 1-37.

Extended report on Wasatch vertebrate fauna with descriptions of twenty-eight new species.

.382 April 20 On the Transition Beds of the Saskatchewan District. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, pp. 9, 10.

.383 April 20 The Herpetology of Florida. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, pp. 10, 11.

Florida as a distinct subdivision of the Austroriparian region.

.384 April 20 The Extinct Batrachia of Ohio. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, p. 16.

Pleuropteryx clavatus and *Hyphasma laevis*, new genera and species, described, and a new species of *Ceraterpeton*.

.385 April 20 On Green-Sand Vertebrata. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, p. 19.

Brief notice of crocodilia and chimaeroid fishes.

.386 April 20 On the Homologies of the Sectorial Tooth of Carnivora. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, pp. 20-23.

Application of theories outlined in No. 335 to the evolution of carnassials. Primitive tibio-astragalar articulation in Eocene carnivora.

.387 May 11 The Feet of *Bathmodon*. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, p. 73. Abstract, "On the Order Amblypoda", *Amer. Nat.* Vol. IX, p. 427.

Characteristics of feet separate Bathmodon and its allies from Proboscidea as a distinct order, Amblypoda, with two suborders, Pintodonta (*Bathmodon*) and Dinocerata (*Uintatherium* and *Loxolophodon*).

.388 June 18 Synopsis of the Vertebrata of the Miocene of Cumberland County, New Jersey. *Proc. Amer. Philos. Soc.* Vol. XIV, 1875, pp. 361-364.

List with a few annotations. *Agabelus* gen. nov.

.389 June 28 On some New Fossil Ungulata. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, pp. 258-261. *Pal. Bull.* No. 19, pp. 1-4. Abstract, *Amer. Journ. Sci.* Ser. 3, Vol. X, 1875, p. 153.

Pliauchenia described with two species. *Hippotherium calamarium* and *Aphelops jemezanus* from Santa Fe marls, New Mexico.

.390 June 28 The Geology of New Mexico. *Pal. Bull.* No. 19, pp. 5-8. Lacks discussion contained in 396, but is otherwise the same.

.391 July 27 On an Indian Kitchenmidden. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, p. 255.

.392 July 27 On Fossil Lemurs and Dogs. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, pp. 255, 256.

Sarcolemur described (Bridger Eocene); *Canis* or *Amphicyon ursinus* from Santa Fe beds.

.393 July 27 On the Antelope-Deer of the Sante Fé Marls. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, p. 257.

'Dicrocerus' (=Merycodus) from Santa Fe beds. This fauna probably Upper Miocene.

.394 July 27 The Phylogeny of the Camels. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, pp. 261, 262.

Evolution of feet and teeth *Poëbrotherium, Procamelus, Pliauchenia, Camelus, Auchenia.*

.395 July 31 Consciousness in Evolution. *Penn Monthly.* Vol. VI, 1875, pp. 560-575.

.396 Aug. 31 The Geology of New Mexico. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, pp. 263-268, 269. Abstract, *Amer. Journ. Sci.* Ser. 3, Vol. X, 1875, pp. 152, 153.

A fuller form of 390. Brief note on Mesozoic and Tertiary

in northern New Mexico, description of *Typothorax coccinarum.*

.397 Aug. 31 On an Extinct Vulturine Bird. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, p. 271.

Vultur umbrosus described from Santa Fe marls.

.398 Sept. 28 On the Cretaceous Beds of Gailsteo. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, pp. 359, 360.

.399 Nov. 26 On the Batrachia and Reptilia of Costa Rica. *Journ. Acad. Nat. Sci. Phila.* Ser. 2, Vol. VIII, 1875, pp. 93-154, 188, Pls. XXIII-XXVIII. Separates November 26, 1875.

New bufoniform genera *Cranopsis, Crepidins* and *Ollotis;* lacertilian genus, *Chalcidolepsis.* Synopses of *Conophis, Coniophanes, Rhadimæa, Tantilla,* and of the genera related to *Stenorhina.* The footnotes include descriptions of a number of new species from Mexico and the new lacertilian genus *Epaphelus.*

.400 Nov. 26 On the Batrachia and Reptilia collected by Dr. John M. Bransford during the Nicaraguan Canal Survey of 1874. *Journ. Acad. Nat. Sci. Phila.* Ser. 2, Vol. VIII, 1875, pp. 155-157. Separates Nov. 26, 1875.

.401 Nov. 26 Report on the Reptiles brought by Prof. James Orton from the Middle and Upper Amazon, and Western Peru. *Journ. Acad Nat. Sci. Phila.* Ser. 2, Vol. VIII, 1875, pp. 159-183. Separates Nov. 26, 1875.

Including a new iguanid genus, *Scytomycterus.*

.402 Nov. 26 Note on the Ichthyology of Lake Titicaca. *Journ. Acad. Nat. Sci. Phila.* Ser. 2, Vol. VIII, 1875, pp. 185-187. Separates Nov. 26, 1875.

Orestias bairdii and *O. ortonii* N. Sp.

.403 Dec. The Relation of Man to the Tertiary Mammalia. *Penn Monthly* Vol. VI, 1875, pp. 879-886.

Read under the title "Indications of Descent Exhibited by the North American Tertiary Mammalia" before the A. A. A. S. Appears as title only in the Proc. A. A. A. S.

.404 Dec. 21 On Fossil Remains of Reptiles and Fishes from Illinois. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, pp. 404-411. Reprint, *Ann. & Mag. Nat. Hist.* Ser. 4, Vol. VII, 1876, pp. 178-184. Abstract, "Interesting Fossils from Illinois", *Amer. Nat.* Vol. IX, 1875, pp. 573, 574.

According to Cope this paper was issued in 1876. See, Cope. 1886.920, p. 286. *Ceratodus vinslooii* Cope.

.405 Dec. 22 On the Supposed Carnivora of the Eocene of the Rocky Mountains. *Proc. Acad. Nat. Sci. Phila* Vol. XXVII, 1875, pp. 444-448. *Pal. Bull.* No. 20, pp. 1-4.
Characters of the Creodonta, proposed as a new suborder of Insectivora.

1876.406 On the Distribution of Batrachia and Reptilia in North America. *Proc. A. A. A. S.* XXIV Meeting, 1875, pp. 197-201.

.407 Jan. 11 On a new Genus of Lophobranchiate Fishes. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVII, 1875, p. 450, Pl. XXV.
Osphyolax.

.408 Feb. 4 On the Remains of Population observed on and near the Eocene Plateau of Northwestern New Mexico. *Proc. Amer. Philos. Soc.* Vol. XIV, 1875, pp. 475-482.
See 364.

.409 March The Academy of Natural Sciences. *Penn. Monthly* Vol. VII 1876, pp. 173-180.

.410 April 18 On a Gigantic Bird from the Eocene of New Mexico. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, pp. 10, 11. *Amer. Journ. Sci.* Ser. 3, Vol. XII, 1876, p. 306 and 493.
Diatryma gigantea.

.411 April 18 On the Theory of Evolution. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, pp. 15-17. Reprint, "The Progress of Discovery of the Laws of Evolution," *Amer. Nat.* Vol. X, 1876, pp. 218-221. *Amer. Journ. Sci.* Ser. 3, Vol. XII, 1876, pp. 309-311.

.412 April 25 On the *Tæniodonta,* a New Group of Eocene Mammalia. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, p. 39.
Partly intermediate between Edentata and Insectivora. Two families. Ectoganidæ and Calamodontidæ. *Esthonyx* and *Anchippodus* related to *Erinaceus.*

.413 April 26 On the Geologic Age of the Vertebrate Fauna of New Mexico. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, pp. 63-66. *Pal. Bull.* No. 21, pp. 1-3. *Journ. de Zoologie* Vol. V, 1876, pp. 307-311. *Amer. Journ. Sci.* Ser. 3, Vol. XII, 1876, pp. 297, 298.
Review of Wasatch fauna and comparison with Suessonian of Europe.

.414 July 11 On some Supposed Lemurine Forms of the Eocene Period. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, pp. 88, 89.
Suborder, Mesodonta based on combination of Creodont

and Primate characters of *'Tomitherium'* of New Mexican Wasatch. [This was due to finding mixed remains of a Creodont and a primate]. Order Bunotheria proposed to include Creodonta, Mesodonta, Insectivora, Tillodonta and Taeniodonta also perhaps Prosimiae.

.415 Aug. — Academies of Science. *Penn Monthly*, Vol. VII, 1876, pp. 640-647.

.416 Aug. 8 — On a New Genus of Fossil Fishes. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, p. 113.
Cyclotomodon vagrans from phosphate beds of Charleston, S. C.

.417 Sept. 5 — Fourth Contribution to the History of the Existing Cetacea. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, pp. 129-139, Pls. III, IV, figs. 1-3.

.418 Sept. 5 — On a New Genus of Camelidae. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, pp. 144-147.
Protolabis, type *P. heterodontus*.

.419 Nov. 13 — Descriptions of some Vertebrate Remains from the Fort Union Beds of Montana. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, pp. 248-261. *Pal. Bull.* No. 22, pp. 1-14.
Ceratodus cruciferus, C. hieroglyphys, new species, and *Mylidaphus bibartitus* new genus and species of fishes. Eighteen species described from Judith River formation, mostly dinosaur teeth; *Dysganus, Diclonius, Monoclonius, Paromychodon, Polythorax, Hedronchus*, new genera.

1877.420 — Report upon the Extinct Vertebrata obtained in New Mexico by Parties of the Expedition of 1874. *Report, U. S. Geogr. Surveys West of the 100th Meridian* (Wheeler) Vol. IV, Part II, pp. 1-370, Pls. XXII-LXXXIII (4to).
Syllænus latifrons from Mesozoic; *Clastis aganus* and *C. integra* from Eocene.

.421 — *Comparative Anatomy. (Frazer) *Johnson's New Universal Cyclopædia*, Vol. I, pp. 1053-1077, figs. 1-36.

.422 — *Osteology (Frazer) *Johnson's New Universal Cyclopædia*, Vol. III, pp. 1008-1016, figs. 1-25.

.423 Jan. 10 — On some Extinct Reptiles and Batrachia from the Judith River and Fox Hills Beds of Montana. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, pp. 340-359. *Pal. Bull.* No. 23, pp. 1-20.
Fifteen species described, mostly from Judith River Cretaceous; *Zapsalis, Uronautes, Champsosaurus, Scapherpeton, Hemitrypus* new genera.

.424 Jan. 23 Explorations in South America. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, p. 264.
Notice of Orton's expedition.

.425 Jan. 23 Cretaceous Vertebrates of the Upper Missouri. *Proc. Acad. Nat. Sci. Phila.* Vol. XXVIII, 1876, p. 266.
Note on correlation of Judith River formation.

.426 Feb. The Suessonian Fauna in North America. *Amer. Nat.* Vol. XI, 1877, pp. 95-99.
General characters of Wasatch fauna compared with Suessonian of Europe.

.427 March 15 Reprint of Synopsis of Fishes of North Carolina with Addenda. March 1877, pp. 1-48.
Date taken from Introduction.

.428 March 19 A Continuation of Researches among the Batrachia of the Coal Measures of Ohio. *Proc. Amer. Philos. Soc.* Vol. XVI, 1877, pp. 573-578. *Pal. Bull.* No. 24, pp. 573-578.
Ichthyacanthus gen. nov. and a new species of *Leptophractus* and *Tuditanus* described.

.429 March 19 On a Dinosaurian from the Trias of Utah. *Proc. Amer. Philos. Soc.* Vol. XVI, 1877, pp. 579-584. *Pal. Bull.* No. 24, pp. 579-584.
Dystrophæus viæmalæ.

.430 March 19 On a New Proboscidian. *Proc. Amer. Philos. Soc.* Vol. XVI, 1877, pp. 584-585. *Pal. Bull.* No. 24, pp. 584, 585.
Caenobasileus tremontigerus. An artefact genus, based on fragments of Tertiary mastodon teeth incorrectly pieced together. See also 448.

.431 April 25 On the Brain of *Coryphodon*. *Proc. Amer. Philos. Soc.* Vol. XVI, 1877, pp. 616-620, Pls. I, II. Abstract, "The Lowest Mammalian Brain," *Amer. Nat.* Vol. XI, 1877, pp. 312, 313.
Description of the braincast of *C. elephantopus* from the New Mexican Wasatch. Separates April 25, 1877. Date from Miss Brown's MSS.

.432 May Discovery of *Laelaps* in Montana. *Amer. Nat.* Vol. XI, 1877, p. 311.
L. incrassatus, no description.

.433 May The Sea Serpents of the Cretaceous Period. *Amer. Nat.* Vol. XI, 1877, p. 311.
Notice of skelton of the *Elasmosaurus serpentinus* from Nebraska, and part of skeleton of *E. orientalis* from Upper Missouri.

.434 May The Dentition of the Herbivorous *Dinosauria* of the Lignitic Period. *Amer. Nat.* Vol. XI, 1877, pp. 311, 312.
Characters of teeth in Trachodontidae.

.435 May The Lowest Mammalian Brain. *Amer. Nat.* Vol. XI, 1877, p. 312.
Brief description of brain of *Coryphodon.*

.436 May 15 Report on the Geology of the Region of the Judith River, Montana, and on Vertebrate Fossils obtained on or near the Missouri River. *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. III, No. 3, pp. 565-597, Pls. XXX-XXXIV.

.437 June The Origin of the Will. *Penn Monthly,* Vol. VIII, 1877, pp. 435-455.

.438 June 15 On the Brain of *Procamelus occidentalis. Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 49-52, Pl. I.
Description of the braincast of *P. "occidentalis"* from the Upper Tertiary of New Mexico (Santa Fe beds). Separates June 15, 1877. Date from Miss Brown's MSS.

.439 Aug. On the Classification of the Recent and Fossil Fishes. *Amer. Nat.* Vol. XI, 1877, p. 501.
Abstract of 491.

.440 Aug. 15 On a Carnivorous Dinosaurian from the Dakota Beds of Colorado. *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. III, No. 4, pp. 805, 806.

.441 Aug. 15 A Contribution to the Knowledge of the Ichthyological Fauna of the Green River Shales. *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. III, No. 4, pp. 807-819. Abstract, "Verbal Communication on a New Locality of the Green River Shales containing Fishes, Insects and Plants in a good state of Preservation," *Pal. Bull.* No. 25, p. 1. Reprinted abstract, "New Fossil Fishes from Wyoming," *Amer. Nat.* Vol. XI, 1877, p. 570.
Sixteen fishes described including 5 new genera and 14 new species.

.442 Aug. 15 On the Genus *Erisichthe. Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. III, No. 4, pp. 821-823.
Discussion of the fragmentary remains on which 4 species have been erected.

.443 Aug. 23 On a New Species of Adocidae from the Tertiary of Georgia. *Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 82-84. *Pal. Bull.* No. 25, pp. 2-4.
Amphiemys gen. nov.

.444 On a gigantic Saurian from the Dakota Epoch of Colorado.
Aug. *Pal. Bull.* No. 25, pp. 5-10.
23 First description of *Camarasaurus supremus* from the Morrison formation near Cañon City, Colorado. Based upon vertebrae. This is a little later than Marsh's first description of an Opisthocoelian (Sauropod) dinosaur from near Morrison, Colo. Marsh, however, used a pre-occupied name (Titanosaurus) so that Cope's name is the earliest available name for an American Opisthocoelian.

.445 Fossil Remains of a Dinosaur. *Proc. Amer. Philos. Soc.*
Aug. Vol. XVI, 1877, pp. 386, 391.
31 Notice of exhibit and title of a paper.

.446 Scratched Figures on Coal Shales. *Proc. Amer. Philos. Soc.*
Aug. Vol. XVI, 1877, p. 391.
31 Notice of *Dystrophaeus* (no name); and of Indian drawings from a mound near Davenport, Iowa.

.447 Vertebral Column of *Elasmosaurus*. *Proc. Amer. Philos.*
Aug. *Soc.* Vol. XVI, 1877, pp. 393, 394. Abstract, "Sea Serpents
31 of the Cretaceous Period," *Amer. Nat.* Vol. XI, 1877, p. 311.
Exhibtion of *Elasmosaurus serpentinus* skeleton, name, no description.

.448 New Species of Mastodon. *Proc. Amer. Philos. Soc.* Vol.
Aug. XVI, 1877, p. 394.
31 See also 430. Notice of *M. tremontinus*—no description [probably meant for "*Caenobasileus tremontigerus*"].

.449 Cast of the Brain Cavity of *Coryphodon elephantopus*. *Proc.*
Aug. *Amer. Philos. Soc.* Vol. XVI, 1877, p. 395.
31

.450 Rare Snakes from Florida. *Amer. Nat.* Vol. XI, 1877,
Sept. p. 565.
Notice of an efficient collector.

.451 The Largest Known Saurian. *Amer. Nat.* Vol. XI, 1877,
Oct. p. 629.

.452 On some New or Little Known Reptiles and Fishes of the
Nov. Cretaceous No. 3, of Kansas. *Proc. Amer. Philos. Soc.*
21 Vol. XVII, 1877, pp. 176-181. *Pal. Bull.* No. 26, pp. 176-181.
Descriptions of species of *Toxochelys* (Chelonia), *Ichthyodectes, Anogmius,* and *Oricardinus,* etc. (Pisces.)

.453 Descriptions of Extinct Vertebrata from the Permian and
Nov. Triassic Formations of the United States. *Proc. Amer.*
21 *Philos. Soc.* Vol. XVII, 1877, pp. 182-193. *Pal. Bull.* No. 26, pp. 182-193 and p. 196. (In the Bulletin the last

paragraph of the original paper is appended at the end of the second article.) Abstract, "Remains of a Huge Saurian in Pennsylvania", *Amer. Nat.* Vol. XI, 1877, p. 629.

Teeth of dinosaurs, etc., from Phœnixville, Pa.; Permian vertebrates from Illinois; *Eryops* skull and skeleton from Permian ("Triassic") of Texas.

.454 Nov. 21 On Reptilian Remains from the Dakota Beds of Colorado. *Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 193-196. *Pal. Bull.* No. 26, pp. 193-196 (For final paragraph see explanation given for 453).

Caulodon (teeth of *Camarasaurus*) and other vertebrates from Morrison formation, Cañon City, Col.; *"Clepsydrops" limbatus* from the Permian of Texas.

.455 Dec. 10 On *Amphicœlias*, a Genus of Saurians from the Dakota Epoch of Colorado. *Pal. Bull.* No. 27, pp. 2-5.

Description of *A. altus* and *"A." latus*. Republished, *Proc. Amer. Philos. Soc.* Vol. XVII, pp. 242-246, and also as *Pal. Bull.* No. 28, same pagination. See 463.

1878.456 Jan. The Relation of Animal Motion to Animal Evolution. *Amer. Nat.* Vol. XII, 1878, pp. 40-48.

The structure of animals is directly modified by their movements, and in adaptation to their habits and environment. [No clear distinction is made between the effects on the individual and upon the phylum.]

.457 Jan. The Saurians of the Dakota Epoch. *Amer. Nat.* Vol. XII, 1878, pp. 56, 57.

Summary of 455.

.458 Jan. *Clepsydrops* in Texas. *Amer. Nat.* Vol. XII, 1878, p. 57.

.459 Jan. The Affinities of the Dinosauria. *Amer. Nat.* Vol. XII, 1878, pp. 57, 58. (Cited by Hay.)

Comments upon Owen's discussion in article describing *Omosaurus*.

.460 Jan. Mount Lebanon Fishes in Dakota. *Amer. Nat.* Vol. XII, 1878, p. 57.

Summary of article in *Bull. U. S. Geol. Survey*. Identity of genera in Mt. Lebanon, Dakota and Westphalia deposits.

.461 Jan. 12 Descriptions of New Vertebrata from the Upper Tertiary Formation of the West. *Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 219-231. *Pal. Bull.* No. 28, pp. 219-231. Abstracts, "New Artiodactyle of the Upper Tertiary."

Amer. Nat. Vol. XII, 1878, p. 58; and "A New Mastodon", Ibid, p. 128.

First descriptions of Deep River fauna (Montana) and Republican River fauna (Kansas-Nebraska); new species from Pleistocene of Oregon and Washington. Two new species each of Cyprinoid genera, *Anchybopsis* and *Alburnops*. First abstract includes tenable descriptions of *Pithecistes*, *Cyclopidius* and *Brachymeryx* new genera. Second abstract, tenable description of *Tetralophodon campistus*.

.462 Jan. 12 On some Saurians found in the Triassic of Pennsylvania by C. M. Wheatley. *Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 231, 232. *Pal. Bull.* No. 28, pp. 231, 232. Abstract, "Triassic Saurians from Pennsylvania", *Amer. Nat.* Vol. XII, 1878, p. 58.

Dinosaur teeth from Phœnixville, Pa.

.463 Jan. 12 On the Vertebrata of the Dakota Epoch of Colorado. *Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 233-247, Pls. (1)-(9). *Pal. Bull.* No. 28, pp. 233-247 (Does not contain plates).

Revised descriptions of *Camarasaurus*, *Amphicoelias* etc., from Morrison formation, Cañon City, Col. See also 455.

.464 Jan. 31 On the Saurians recently discovered in the Dakota Beds of Colorado. *Amer. Nat.* Vol. XII, 1878, pp. 71-85, figs. 1-6, 9-17.

Descriptions with figures of *Camarasaurus* and *Amphicoelias*, description of *Tichosteus*.

.465 Jan. 31 Pliocene Man. (Read before the Amer. Philos. Soc.) *Amer. Nat.* Vol. XII, 1878, pp. 125, 126. *Proc. Amer. Philos. Soc.* Vol. XVII, 1878, p. 292.

List of species of fossil mammals (Lower Pleistocene) found with obsidian arrow heads [Fossil Lake, Oregon]. While the *Proc. Amer. Philos. Soc.* is supposed to contain the original and the *Amer. Nat.* the reprint, the latter was the first to be published apparently.

.466 Jan. 31 Palaeontology of Georgia. *Amer. Nat.* Vol. XII, 1878, p. 128.

Note on position of *Erisichthe*. Cited by Hay.

.467 Jan. 31 The Snout of Fishes from the Kansas Chalk. *Amer. Nat.* Vol. XII, 1878, p. 129.

Abstract, eight lines.

.468 Jan. 31 A New Genus of Oreodontidæ. *Amer. Nat.* Vol. XII, 1878, p. 129.

Description of *Ticholeptus zygomaticus*, gen. et sp. nov. from Deep River beds of Montana.

.469 Jan. 31 Note on Fossils obtained by Mr. Russell S. Hill, including Bones of *Protostega gigas*. *Amer. Nat.* Vol. XII, 1878, p. 137. Cited by Hay.

.470 Feb. 5 Descriptions of Fishes from the Cretaceous and Tertiary Deposits west of the Mississippi River. *Bull. U. S. Geol. and Geogr. Survey of the Territories*, Ser. IV, No. 1, pp. 67-77.
Two new genera and eleven new species described.

.471 Feb. 5 Professor Owen on the *Pythonomorpha*. *Bull. U. S. Geol. and Geogr. Survey of the Territories*, Ser. IV, No. 1, pp. 299-311.

.472 March A Texas Cliff Frog. *Amer. Nat.* Vol. XII, 1878, p. 186.
Lithodytes n. sp. Note on habits.

.473 March A New Genus of *Dinosauria* from Colorado. *Amer. Nat.* Vol. XII, 1878, pp. 188, 189.
Description of *Hypsirophus obscurus* gen. et sp. nov.

.474 March A New Deer from Indiana. *Amer. Nat.* Vol. XII, 1878, p. 189.
Description of *Cariacus dolichopsis* n. sp. from Pleistocene of Indiana.

.475 March 9 Synopsis of the Cold Blooded Vertebrata, procured by Prof. James Orton during his Exploration of Peru in 1876-1877. *Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 33-49.
Nineteen fishes listed, eight being new.

.476 March 9 Reptilian Bone Bed in Eastern Illinois. (On the Vertebrata of the Bone Bed in Eastern Illinois.) *Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 2, 52-63.

.477 March 9 On some New and Little Known Reptiles and Fishes from the Austroriparian Region. *Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 63-68.
Nine batrachians, twenty-six reptiles and eleven fishes from Georgia, South Carolina, Florida. Two new species of *Lepomis*, and *Xystroplites longimanus* Nov. Gen. et Sp. described.

.478 March 9 Tenth Contribution to the Herpetology of Tropical America. *Proc. Amer. Philos. Soc.* Vol. XVII, 1877, pp. 85-98.

.479 April Contribution to the Fossil Flora of the Western Territories. Part II, The Tertiary Flora, by Leo Lesquereux (Review). *Amer. Nat.* Vol. XII, 1878, pp. 243-246.

Criticism of Lesquereux' conclusions upon the Cretaceous-Tertiary boundary formations in the Rocky Mountain region.

.480 April — A New Genus of Cystignathidæ from Texas. *Amer. Nat.* Vol. XII, 1878, pp. 252, 253.
Syrrhopus marnockii.

.481 May — The Homology of the Chevron Bones. *Amer. Nat.* Vol. XII, 1878, p. 319.
Chevron bones are homologous with intercenta of dorsal and cervical vertebræ of Permian reptiles.

.482 May — The Structure of *Coryphodon.* *Amer. Nat.* Vol. XII, 1878, pp. 324-326. Abstract, *Nature,* Vol. XVIII, 1878, p. 67.
Reply to Marsh's criticism in *Nature,* Vol. XVII, 1878, p. 340, of Cope's description of brain and foot structure of this genus.

.483 May 3 — Descriptions of New Extinct Vertebrata from the Upper Tertiary and Dakota Formations. *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. IV, No. 2, pp. 379-396.

.484 May 8 — Descriptions of Extinct Batrachia and Reptilia from the Permian Formation of Texas. *Proc. Amer. Philos. Soc.* Vol. XVII, 1878, pp. 505-530. *Pal. Bull.* No. 29, pp. 505-530. Abstract, "A New Fauna," *Amer. Nat.* Vol. XII, 1878, pp. 327, 328.
Descriptions of *Diadectes, Bolosaurus, Pariotichus, Ectocynodon, Clepsydrops natalis* skeleton, *Dimetrodon, Epicordylus* (=*Eryops*), *Empedocles* (=*Diadectes*), *Theropleura, Parioxys, "Cricotus heteroclitus", Zatrachys, Trimerorhachis, Rachitomus* (=*Eryops*), etc. With the exception of *Eryops,* these are the first descriptions of the Texas Permian fauna.

.485 June — A New Opisthocoelous Dinosaur. *Amer. Nat.* Vol. XII, 1878, p. 406. *Reprint, Ann. & Mag. Nat. Hist.* Ser. 5, Vol. II, 1878, p. 194.
Description of *Epanterias amplexus* gen. et sp. nov. from Morrison formation, Cañon City, Col.

.486 June — Prof. Marsh on Permian Reptiles. *Amer. Nat.* Vol. XII, 1878, pp. 406-408.
Criticism of Marsh's paper in *Amer. Journ. Sci.* for May, 1878.

.487 June — Fossorial Reptiles. *Amer. Nat.* Vol. XII, 1878, p. 408.
Humeri of certain Permian reptiles appear to be of fossorial type.

.488 Synopsis of the Fishes of the Peruvian Amazon, obtained
June by Prof. Orton during his Expeditions of 1873 and 1877.
10 *Proc. Amer. Philos. Soc.* Vol. XVII, 1878, pp. 673-701.
One hundred and twenty species listed from upper Amazon. Three new genera and thirty new species established.

.489 Proceedings of the Academy of Natural Sciences of Phila-
July delphia, September to December 1877. *Amer. Nat.* Vol. XII, 1878, pp. 459-461.
Critical comment on President's Annual Report. Unsigned Review. Cited by Frazer.

.490 The Species of Rhinoceros of the Loup Fork Epoch. *Amer.*
July *Nat.* Vol. XII, 1878, pp. 488, 489.
Diagnosis of *Aphelops fossiger* and *malacorhinus* from Republican River beds of Kansas.

.491 On the Classification of the Extinct Fishes of the Lower
Aug. Types. *Proc. A. A. A. S.* XXVI Meeting, 1877, pp. 292-300. (For abstract see 439.)
Critical discussion of bases of differentiation between the lower forms of fishes.

.492 The Report of the Committee of the American Association
Aug. of 1876 on Biological Nomenclature. *Amer. Nat.* Vol. XII, 1878, pp. 517-525.
Results of a questionnaire.

.493 Review—The Relation of the Mosaic Cosmography to Sci-
Aug. ence, by C. B. Warring, Ph. D. *Amer. Nat.* Vol. XII, 1878, pp. 547-549. Unsigned. Cited by Frazer.

.494 Note on the Prong-Horned Antelope. *Amer. Nat.* Vol. XII,
Aug. 1878, p. 557.
Shedding of the horns is not periodical or even frequent.

.495 A New Species of *Amphicœlias*. *Amer. Nat.* Vol. XII, 1878,
Aug. pp. 653, 654, 1 fig.
Description of *A. fragillimus* from Morrison beds near Cañon City, Col. [part of a gigantic vertebrate].

.496 A New *Diadectes*. *Amer. Nat.* Vol. XII, 1878, p. 565.
Aug. Description of *D. molaris* from Permian of Texas. Unsigned. Cited by Hay and Frazer.

.497 Des rapports entre le mouvement et l'évolution chez les
Aug. animaux. *Revue internat. des Sciences,* Tre Anné, No. 31,
1 pp. 138-141. See 456.

.498 Aug. 29 On the Saurians of the Dakota Cretaceous Rocks of Colorado. *Nature,* Vol. XIII, Aug. 29, p. 476. *Proc. British A. A. S.* 1878, p. 545.
Abstract of paper read before British A. A. S. 1878.

.499 Aug. 29 On the Remains of a Permian Fauna in North America. *Nature,* Vol. XIII, Aug. 29, 1878, p. 482.
Abstract of paper read before the British A. A. S. Title only in Proc. British A. A. S. 1878, p. 571.

.500 Sept. The Vertebræ of *Rachitomus.* *Amer. Nat.* Vol. XII, 1878, p. 633.
Construction of the vertebræ. *Eryops* is probably similar.

.501 Sept. A Fossil Walrus discovered at Portland, Maine. *Amer. Nat.* Vol. XII, 1878, p. 633.
Notice of discovery. Skeleton in Museum of Portland Nat. Hist. Soc. Unsigned. Cited by Hay.

.502 Nov. The Herpetology of New Guinea. *Amer. Nat.* Vol. XII, 1878, p. 751.
Review of an article by H. E. Sauvage in the Bulletin, Société philomatique, Paris.

.503 Nov. The Fauna of the Lowest Tertiary of France. *Amer. Nat.* Vol. XII, 1878, pp. 761, 762.
Notice of the palæontological discoveries of Dr. Lemoine in the Lowest Tertiary of France.

.504 Dec. The Excursions of the Geological Society of France for 1878. *Amer. Nat.* Vol. XII, 1878, pp. 771-776.

.505 Dec. The Principal Characters of American Cretaceous Dinosaurs. *Amer. Nat.* Vol. XII, 1878, pp. 811, 812.
Critical review of Marsh's paper in Amer. Journ. Sci. with this title. Unsigned. Cited by Frazer.

.506 Dec. The Theromorphous Reptilia. *Amer. Nat.* Vol. XII, 1878, pp. 829, 830.
Abstract with diagnoses of orders and suborders; *Dimetrodon cruciger* sp. nov. from Permian of Texas. Abstract of paper read before the National Academy of Sciences, Nov. 7, 1878.

.507 Dec. 26 On some of the Characters of the Miocene Fauna of Oregon. *Proc. Amer. Philos. Soc.* Vol. XVIII, 1878, pp. 63-78. *Pal. Bull.* No. 30, pp. 1-16. Abstract, "Miocene Vertebrata of Oregon," *Amer. Nat.* Vol. XII, 1878, p. 833.
Based upon collections of Sternberg, Wortman and Day in

the John Day basin. Chiefly Rodents, Carnivores and Horses from the John Day formation.

1879.508 Jan. 4 Palæontological Report of the Princeton Scientific Expedition of 1877. *Amer. Nat.* Vol. XIII, 1879, pp. 32, 33.

Unsigned Review of "Contributions from the Museum of Geology and Archæology of Princeton College. No. 1-, Palæontological Report etc., by Henry F. Osborn, W. B. Scott and Francis Spier, Jr." Cited by Hay.

.509 Jan. 4 Letter from O. C. Marsh, etc. transmitting the Report on the Scientific Surveys of the Territories. *Amer. Nat.* Vol. XIII, 1879, pp. 35-37.

Review of, "Letter from O. C. Marsh, vice-president and acting president of the National Academy of Sciences, transmitting, in obedience to law, the Report on the Scientific Surveys of the Territories made by the National Academy of Sciences, Senate Mis. Doc. No. 19." Objections to plan for discontinuance of existing U. S. geological surveys and replacement by a new survey.

.510 Feb. 4 Extinct Mammalia of Oregon. *Amer. Nat.* Vol. XIII, 1879, p. 131.

Tenable description of *Enhydrocyon* gen. nov. For full paper see 516.

.511 Feb. 4 The Necks of Sauropterygia. *Amer. Nat.* Vol. XIII, 1879, p. 132.

Progressive shortening of the neck during the Cretaceous.

.512 Feb. 4 The Scales of *Liodon*. *Amer. Nat.* Vol. XIII, 1879, p. 132. Six lines.

Unsigned. A brief note calling attention to observations of Professor Snow and to his paper in Review of Science and Industry—Hay.

.513 Feb. 27 The Origin of the Specialized Teeth of the Carnivora. *Amer. Nat.* Vol. XIII, 1879, pp. 171-173. *Ann. & Mag. Nat. Hist.* Ser. 5, Vol. III, 1879, pp. 391, 392.

Explanation of the mechanical causes operating to evolve the carnassial teeth.

.514 Feb. 27 *Merycopater* and *Hoplophoneus*. *Amer. Nat.* Vol. XIII, 1879, p. 197.

Note on John Day fossil mammalia. *Merycopater* gen. nov. (=*Agriochærus*); *Machærodus brachyops* transferred to *Hoplophoneus*.

.515 Feb. 28 The Relations of the Horizons of Extinct Vertebrata of Europe and North America. *Bull. U. S. Geol. and Geogr. Survey of the Territories*, Ser. V, No. 1, pp. 33-54.

.516 Feb. 28 Observations on the Faunæ of the Miocene Tertiaries of Oregon. *Bull. U. S. Geol. and Geogr. Survey of the Territories.* Vol. V, No. 1, pp. 55-69.

For abstract see 510.

.517 March 13 A Review of the Modern Doctrine of Evolution. (Read before the California Academy of Sciences, October 27, 1879.) *"*Scientific Press" Supplement,* November, 1879, pp. 1-28. Abstract, *Amer. Nat.* Vol. XIV, 1880, pp. 166-179, 260-271; 27 figs. *Separates, Philadelphia, March 13, 1880, pp. 166-178, 261-272; 27 figs. (Date from Miss Brown's MSS.)

The evidence for evolution—ontogeny and phylogeny; the laws of evolution—acceleration—adaptation—kinetogenesis; the metaphysics of evolution; the morals of evolution.

.518 March 26 A New Genus of Perissodactyla. *Amer. Nat.* Vol. XIII, 1879, pp. 270, 271.

Anchisodon gen. nov. type *Hyracodon quadriplicatus* from White River beds of N. E. Colorado.

.519 March 26 New Genus of Ichthyopterygia. *Amer. Nat.* Vol. XIII, 1879, p. 271.

Notice of Marsh's article describing *Sauranodon* gen. nov. (=*Baptanodon*). Unsigned. Cited by Hay.

.520 April Une lettre de M. Cope (de Philadelphie) au suject d'une question de priorité relative à l'emploi des noms de *Dinoceras* et de *Brontotherium*. *Le Naturaliste,* Vol. I, No. 1, 1879, pp. 2, 3.

.521 April 22 Statements in Regard to the Bulletin of the U. S. Geological and Geographical Survey of the Territories, Vol. VI, No. I. *Proc. Amer. Philos. Soc.* Vol. XVIII, 1879, p. 211.

.522 May The Amyzon Tertiary Beds. *Amer. Nat.* Vol. XIII, 1879, p. 332.

Amyzon fish fauna distinct from that of Green River, probably later than Bridger horizon.

.523 May Gaudry on Permian Vertebrata. *Amer. Nat.* Vol. XIII, 1879, pp. 332, 333.

Actinodon Gaudry compared with *Rhachitomus* Cope (= *Eryops*) and *Euchirosaurus* with *Dimetrodon* of Texas Permian. Unsigned. Given on Dr. Matthew's authority.

.524 May A Sting Ray from the Green River Shales of Wyoming. *Amer. Nat.* Vol. XIII, 1879, p. 333.

Xiphotrygon acutidens described.

.525 American Aceratheria. *Amer. Nat.* Vol. XIII, 1879, pp.
May 333, 334.
Aceratherium (=*Cænopus*) *truguianum* n. sp. described from John Day formation of Oregon. Diagnosis of *Aphelops*.

.526 The Lower Jaw of *Loxolophodon*. *Amer. Nat.* Vol. XIII,
May 1879, p. 334.
Notice of article in *Amer. Journ. Sci.* by Osborn and Spier.

.527 New Jurassic Dinosauria. *Amer. Nat.* Vol. XIII, 1879, pp.
May 402-404, 3 cuts.
20 *Camarasaurus leptodirus* and *Hypsirhophus seeleyanus* described from Morrison beds near Cañon City, Col.

.528 Vertebræ of a New Species of *Camelosaurus*. *Proc. Amer.*
June *Philos. Soc.* Vol. XVIII, 1879, p. 211.
3

.529 A Contribution to the Zoology of Montana. *Amer. Nat.*
June Vol. XIII, 1879, pp. 432-441.
17 Notes chiefly on amphibian and fish fauna in parts of Western Montana.

.530 Ryder on the Mechanical Genesis of Tooth Forms. *Amer.*
June *Nat.* Vol. XIII, 1879, pp. 446-449.
17 Review of articles by John A. Ryder in *Proc. Acad. Nat. Sci. Phila.*, 1878-9. Kinetogenesis. Unsigned. Given on Dr. Matthew's authority.

.531 Another *Siredon*. *Amer. Nat.* Vol. XIII, 1879, pp. 456, 457.
June *Siredon tigrinus* Velasco, probably identical with *Amblystoma*
17 *mavortium* Baird.

.532 *Lota maculosa* in the Susquehanna River. *Amer. Nat.* Vol.
June XIII, 1879, p. 457.
17

.533 A New *Anchitherium*. *Amer. Nat.* Vol. XIII, 1879, pp.
June 462, 463.
17 *A. præstans* described from John Day formation of Oregon. Type of *Kalobatippus* Osborn, 1916.

.534 A Decade of Dogs. *Amer. Nat.* Vol. XIII, 1879, p. 530.
Aug. List of ten species from John Day formation, Oregon.

.535 The Modern Museum. *Penn Monthly* Vol. X, 1879, pp.
Aug. 598-605.

.536 Eleventh Contribution to the Herpetology of Tropical Amer-
Aug. ica. *Proc. Amer. Philos. Soc.* Vol. XVIII, 1879, pp. 261-277.
11 For the states of Chihuahua, Guanjuato, and the Isthmus

of Tehuantepec, Mexico, Costa Rica, Santa Domingo, Dominica, Tobago, and northwest Bolivia. Including the new genera of snakes, *Procinura* and *Malachylodes* from Mexico, and synopses of the genera *Syrrhophus* and *Cystignathus*.

.537 Aug. 12 On the Genera of Felidæ and Canidæ. *Proc. Acad. Nat. Sci. Phila.* Vol. XXXI, 1879, pp. 168-184 (published Aug. 12), pp. 185-194 (published Nov. 4). *Ann. & Mag. Nat. Hist.*, Ser. 5, Vol. V, 1880, pp. 36-45, 92-108.

.538 Sept. 6 On the Extinct Species of *Rhinocerida* of North America and their Allies. (Read before the National Academy of Sciences, April, 1879.) *Bull. U. S. Geol. and Geogr. Survey of the Territories,* Ser. V. No. 2, pp. 227-237. An adaptation of this paper, "On the Extinct American Rhinoceroses and their Allies," appeared in *Amer. Nat.* Vol. XIII, 1879, pp. 771a-771j, figs. 1-8. Abstract, *Science News* Vol. I, p. 221.
American Naturalist article contains figures of *Aphelops fossiger, megalodus* and *malacorhinus* skulls.

.539 Oct. The California Gray Whale. *Amer. Nat.* Vol. XIII, 1879, p. 655.

.540 Oct. The Japanese Dog. *Amer. Nat.* Vol. XIII, 1879, pp. 655, 656.
Dysodus pravus, additional notes upon.

.541 Dec. The Fishes of Klamath Lake, Oregon. *Amer. Nat.* Vol. XIII, 1879, pp. 784, 785.
Annotated list of species found.

.542 Dec. The Cave Bear of California. *Amer. Nat.* Vol. XIII, 1879, p. 791. Reprint, *Ann. & Mag. Nat. Hist.*, Ser. 5, Vol. V, 1880, pp. 260, 261. Reprint, *Amer. Journ. Sci.* Vol. XIX, 1880, p. 155.
Description of *Arctotherium simum* sp. nov. from Shasta Co., Cal.

.543 Dec. Scientific News. *Amer. Nat.* Vol. XIII, 1879, pp. 798a, 798b. Unsigned. Cited by Hay and Frazer.
Report of Cope's exploration of John Day, N. E. Colorado, and Cañon City fossil fields. Descriptions of *Archælurus debilis* and *Hoplophoneus platycopis.*

.544 Dec. California Academy of Sciences, November 3. *Amer. Nat.* Vol. XIII, 1879, pp. 800, 801.
Remarks on *Arctotherium simus* and *Xantusia riversiana.*

.545 Dec. 4 Second Contribution to a Knowledge of the Miocene Fauna of Oregon. *Proc. Amer. Philos. Soc.* Vol. XVIII, 1879, pp. 370-376. *Pal. Bull.* No. 31, pp. 1-7 (this was the first to be

published). Abstract, "Miocene Fauna of Oregon," *Amer. Nat.* Vol. XIV, 1880, p. 60.

Continuation of researches upon collections made by Wortman, Sternberg and Day in 1878-9 in the John Day basin. Chiefly descriptions of carnivora, rodents, peccaries and Agriochoeri from the John Day formation.

1880.546 Sur les Relations des niveaux de vertébrés éteints dans l'Amerique du Nord et en Europe. *Comptes rendus, Congrés internat. de Géol.*, Paris, 1878, pp. 144-164.

.547 Sur le Report of the Committee of the American Association of 1876 on Biological Nomenclature. *Comptes rendus, Congrés internat. de Géol.*, Paris, 1878, pp. 268-271.

.548 On the Zoological Position of Texas. *Bull. U. S. Nat. Museum*, No. 17, pp. 1-51.

.549 Jan. 2 (On the Proposed Reorganization of the Philadelphia Academy of Natural Sciences.) Unsigned. *Amer. Nat.* Vol. XIV, 1880, pp. 38-42, 356-359.

.550 Jan. 2 Pliocene Man. [Remarks on fossil Vertebrates from California, *Elotherium, Mastodon obscurus*—Hay.] *Amer. Nat.* Vol. XIV, 1880, pp. 60-62.

.551 Jan. 31 Hill's Kansas Expeditions. *Amer. Nat.* Vol. XIV, 1880, pp. 141, 142.

Unsigned. Cited by Hay and Frazer. Notice of collections made in Republican River basin.

.552 Jan. 31 Hulke on *Ornithopsis* of Seeley. *Amer. Nat.* Vol. XIV, 1880, p. 142.

Unsigned. Cited by Frazer. Notice of Hulke's paper, *Q. J. G. S.* Vol. 35, pp. 752-762.

.553 Jan. 31 Filhol on the Fauna of St. Gerand le Puy. *Amer. Nat.* Vol. XIV, 1880, p. 142.

Unsigned. Cited by Frazer. Notice of Filhol's Memoir in *Ann. Sci. Géol.* Vol. X, No. 3, 1879, Vol. XI.

.554 Jan. 31 Notes on Sabre-tooths. *Amer. Nat.* Vol. XIV, 1880, pp. 142, 143.

Pogonodon gen. nov. and *Hoplophoneus cerebralis* sp. nov. from John Day formation of Oregon.

.555 Feb. 25 [Tariff on Scientific Apparatus.] *Amer. Nat.* Vol. XIV, 1880, pp. 190-192.

Unsigned editorial. Cited by Frazer. Scientific specimens and apparatus should be admitted free whether or not intended for sale.

.556 The Refutation of Darwinism. *Amer. Nat.* Vol. XIV, 1880,
Feb. pp. 192, 193.
25 Unsigned. Review of, "The Refutation of Darwinism and the Converse Theory of Development, based exclusively upon Darwin's Facts, etc., by T. Warren O'Neill." Cited by Frazer.

.557 A New *Hippidium*. *Amer. Nat.* Vol. XIV, 1880, p. 223.
Feb. *H. spectans* from John Day basin of Oregon (Rattlesnake
25 formation) now referred to *Pliohippus*.

.558 On the Foramina perforating the Posterior Part of the
March Squamosal Bone of the Mammalia. *Proc. Amer. Philos. Soc.*
2 Vol. XVIII, 1880, pp. 452-461, figs. 1-6. Abstract, *Amer. Nat.* Vol. XIV, 1880, pp. 287, 288.
Taxonomic value of the squamosal foramina. Pp. 452-456 appeared on March 2; pp. 457-461, March 6.

.559 Marsh on Jurassic Dinosauria. *Amer. Nat.* Vol. XIV, 1880,
March p. 302.
21 Unsigned. Cited by Hay and Frazer. Notice of Marsh's article on *Stegosaurus* in Amer. Journ. Sci. (3) Vol. XIX, pp. 253-259, Pl. VI-XI.

.560 The Manti Beds of Utah. *Amer. Nat.* Vol. XIV, 1880, pp.
March 303, 304.
21 May be equivalent to Green River formation. Fossils, *Crocodilus, Clastis* and *Priscacara*.

.561 The skull of *Empedocles*. *Amer. Nat.* Vol. XIV, 1880, p. 304.
March Description of the skull of *E. molaris* from Permian of
21 Texas. Now referred to *Diadectes*. Cotylosauria proposed as a suborder of Theromorpha to include *Diadectes*.

.562 A New Genus of Tapiroids. *Amer. Nat.* Vol. XIV, 1880, pp.
April 382, 383.
27 *Triplopus cubitalis* gen. et sp. nov. from Eocene of Washakie basin of Wyoming.

.563 The Structure of the Permian Ganocephala. *Amer. Nat.*
April Vol. XIV, 1880, pp. 383, 384.
27 Characters of vertebræ scapular and pelvic arches in *Eryops*.

.564 [Statements concerning the election of officers for the Phila-
April delphia Academy of Natural Sciences.] *Amer. Nat.* Vol.
27 XIV, 1880, pp. 390, 391.
Unsigned.

565 May 21 Traquair on *Platysomidæ*. *Amer. Nat.* Vol. XIV, 1880, pp. 439, 440.
Review: On the Structures and Affinities of Platysomidæ, by Ramsay H. Traquair, Trans. Roy. Soc. Edinburgh Vol. XXIX, 1879.

.566 May 21 Corrections of the Geological Maps of Oregon. *Amer. Nat.* Vol. XIV, 1880, pp. 457, 458.
Coast Range formations Tertiary, not Archæan. Sequence of formations in the John Day basin.

.567 June 5 Second Contribution to the History of the Vertebrata of the Permian Formation of Texas. *Proc. Amer. Philos. Soc.* Vol. XIX, 1880, pp. 38-58, Pls. I-VI. *Pal. Bull.* No. 32, pp. 1-22, Pls. I-IV. (The plates were not published until May 2, 1881.) Abstract, *Amer. Nat.* Vol. XIV, 1880, p. 610.
Ectosteorhachis nitidus Nov. Gen. et Sp.

.568 June 18 The Geological Record. *Amer. Nat.* Vol. XIV, 1880, pp. 511, 512.
Unsigned. Cited by Hay. Criticism of references to Cope's recent discoveries.

.569 June 21 A New Genus of Rhinocerontidæ. *Amer. Nat.* Vol. XIV, 1880, p. 540.
Peraceras superciliosus gen. et sp. nov. described. *Aphelops malacorhinus* referred to this genus. Both from Republican River beds (Pliocene) of Nebraska.

.570 June 23 On certain Tertiary Strata of the Great Basin. *Proc. Amer. Philos. Soc.* Vol. XIX, 1880, pp. 60-62.

.571 July 22 Extinct Batrachia. *Amer. Nat.* Vol. XIV, 1880, pp. 609, 610.
Discoveries of Dr. Anton Fritsch in the Permian "Gaskohle" of Bohemia, and of Dr. Wiedersheim in the "Bunter Sandstein" of Switzerland: discussion of the genus *Cricotus*.

.572 July 22 The Genealogy of the American Rhinoceroses. *Amer. Nat.* Vol. XIV, 1880, pp. 610, 611.
Triplopus ancestral to *Aphelops* through *Cænopus* gen. nov. From *Aphelops, Peraceras* leads into African rhinoceroses and *Ceratorhinus* into *Rhinoceros* proper. *Aceratherium* side branch.

.573 Aug. 3 On the Genera of the *Creodonta*. *Proc. Amer. Philos. Soc.* Vol. XIX, 1880, pp. 76-82. Synopsis, *Kosmos,* Vol. X, 1880, pp. 299, 300.
Revised classification and discussion of affinities and phylogeny. The Miacidæ and Mesonychidæ are here included in

the order; the former as ancestors of the Canidæ, while the Felidæ are derived from Oxyænidæ. Pp. 76-80 appeared Aug. 3; pp. 81, 82 were printed Sept. 9.

.574 Sept. [Government aid to Pure Science.] *Amer. Nat.* Vol. XIV, 1880, pp. 654, 655.
Unsigned. Cited by Frazer.

.575 Sept. 21 [Biology at the American Association at Boston. Remarks on the views of Prof. Barker and Mr. Agassiz concerning Evolution as stated by them before the A. A. A. S. in 1880.] *Amer. Nat.* Vol. XIV, 1880, pp. 725-728.

.576 Sept. 21 The Bad Lands of Wind River and their Fauna. *Amer. Nat.* Vol. XIV, 1880, pp. 745-748.
Notice of Wortman's collections of fossil mammals for Prof. Cope. Descriptions of *Protopsalis* and *Lambdotherium* new genera, and ten new species.

.577 Oct. 2 [Obligations of Educational and Charitable Institutions.] *Amer. Nat.* Vol, XIV, 1880, pp. 793-795.
Unsigned. Cited by Frazer.

.578 Nov. 25 On the Extinct Cats of America. *Amer. Nat.* Vol. XIV, 1880, pp. 833-858, figs. 1-15.
Classification and phylogeny; descriptions of White River and John Day species with figures of the best known John Day forms, and of *Smilodon necator* from Pampean of South America.

.579 Nov. 25 [The Permanent Exhibition for Philadelphia.] *Amer. Nat.* Vol. XIV, 1880, pp. 881, 882.
Unsigned. Cited by Frazer.

.580 Nov. 25 The Northern Wasatch Fauna. *Amer. Nat.* Vol. XIV, 1880, pp. 908, 909.
Additional notes on Wind River fauna with descriptions of two new species.

.581 Dec. 18 *Nimravidæ* and Miocene *Canidæ*. *Science* Vol. I, 1880, p. 303.
Abstract of paper read before the National Academy of Sciences, New York, 1880. See 591.

.582 Dec. 31 The United States Geological Survey. *Amer. Nat.* Vol. XV, 1881, pp. 39-41.
Unsigned. Cited by Frazer.

.583 Dec. 31 On the Organization of Academies of Science. *Amer. Nat.* Vol. XV, 1881, pp. 41, 42.
Unsigned. Cited by Frazer.

.584 A New Genus of Catostomidæ. *Amer. Nat.* Vol. XV.
Dec. 1881, p. 59.
31 *Lipomyzon* from Klamath Lake, Oregon.

.585 The Vertebrata of the Eocene of the Wind River Basin.
Dec. *Amer. Nat.* Vol. XV, 1881, pp. 74, 75.
31 Tenable description of *Bathyopsis fissidens.* Abstract of 592.

1881.586 The Fishes of Pennsylvania. *Report,* (Pennsylvania) *State Commissioner of Fisheries,* 1879-1880, pp. 60-137, Plates I-XXVI.

A systematic and descriptive account of the 157 species then known. It was reprinted in the report for 1881 and 1882, published in 1883.

.587 [The Tariff Laws of the United States.] *Amer. Nat.* Vol.
Jan. XV, 1881, pp. 124-126.
25 Unsigned editorial. Cited by Frazer.

.588 Catalogue of the Vertebrata of the Permian Formation of
Jan. the United States. *Amer. Nat.* Vol. XV, 1881, pp. 162-164.
25 List, with references to publication of 51 species.

.589 On some New Batrachia and Reptilia from the Permian
Feb. Beds of Texas. *Bull. U. S. Geol. and Geogr. Survey of the*
11 *Territories* Vol. VI, No. 1, pp. 79-82.

.590 On a Wading Bird from the Amyzon Shales. *Bull. U. S.*
Feb. *Geol. and Geogr. Survey of the Territories* Vol. VI, No.
11 1, pp. 83-85. Abstract, "A New Fossil Bird," *Amer. Nat.* Vol. XV, 1881, p. 253.

Notice of *Charadrius sheppardianus.*

.591 On the *Nimravidæ* and the *Canidæ* of the Miocene Period.
Feb. *Bull. U. S. Geol. and Geogr. Survey of the Territories* Vol.
11 VI, No. 1, pp. 165-181. See 581.

.592 On the Vertebrata of the Wind River Eocene Beds of Wyo-
Feb. ming. *Bull. U. S. Geol. and Geogr. Survey of the Terri-*
11 *tories* Vol. VI, No. 1, pp. 132-202. Abstract, "The Vertebrata of the Eocene of the Wind River Basin", *Amer. Nat.* Vol. XV, 1881, pp. 74, 75. See 585.

Bathyopsis fissidens gen. et sp. nov. described in abstract. *Clastis* sp. and *Pappichthys* named from scales and vertebræ. Read by title before the Amer. Philos. Soc. Dec. 3, 1880, but withdrawn for publication by the U. S. Geol. Survey.

.593 [Laws of Nomenclature.] *Amer. Nat.* Vol. XV, 1881, pp.
Feb. 219-221.
24 Unsigned editorial.

.594 The Japanese Lap Dog. *Amer. Nat.* Vol. XV, 1881, pp.
Feb. 233, 234.
24

.595 Extinct Palæozoic Fishes from Canada. *Amer. Nat.* Vol.
Feb. XV, 1881, pp. 252, 253.
24 Notice of article by Whiteaves on discoveries in Devonian of Baie des Chaleurs. Unsigned. Cited by Hay.

.596 A New Fossil Bird. *Amer. Nat.* Vol. XV, 1881, p. 253.
Feb. Notice of Dr. Allen's description of *Palæospiza bella*—Hay,
24 and of *Charadius sheppardianus* from Amyzon beds of Colorado. Type of latter in Amer. Mus.

.597 Geological News. *Amer. Nat.* Vol. XV, 1881, pp. 254, 340,
Feb. 413, 1023.
24 Unsigned notes. Cited by Hay. Brief notes of various papers on vertebrate palæontology. *Stegosaurus=Hypsirhophus.*

.598 On the Origin of the Foot Structures of the Ungulates.
March *Amer. Nat.* Vol. XV, 1881, pp. 269-273, figs. 1-5.
25 Explanation of the origin of specialized foot structures of ungulates through kinetogenesis.

.599 Mammalia of the Lower Eocene Beds. *Amer. Nat.* Vol.
March XV, 1881, pp. 337, 338.
25 First descriptions of fossil mammals from the Puerco of New Mexico. *Periptichus carinidens, Deltatherium fundaminis,* new genera and species.

.600 Filhol on *Proælurus.* *Amer. Nat.* Vol. XV, 1881, pp. 339,
March 340.
25 Unsigned. Cited by Frazer. Notice of Filhol's memoir on *P. lemanensis* in Bull. soc. sci. phys. et nat.

.601 The Classification of the Perissodactyla. *Amer. Nat.* Vol.
March XV, 1881, p. 340.
25 Tabular key, taken from Rept. U. S. G. S. Terr. (Tertiary Vertebrata.)

.602 The Systematic Arrangement of the Order *Perissodactyla.*
May *Proc. Amer. Philos. Soc.* Vol XIX, 1881, pp. 377-401,
14 figs. 1, 2.
Key to families, geological distribution of genera, characters of each family and key to included genera; descriptions of *Triplopus cubitalis* and *T. amarorum,* pp. 377-386, printed May 14; pp. 387-401, May 16.

.603 Note on the Structure of the Posterior Foot of *Toxodon.*
May *Proc. Amer. Philos. Soc.* Vol. XIX, 1881, pp. 402, 403.
16 *Ann. & Mag. Nat. Hist.*, Ser. 5, Vol. VIII, 1881, pp. 389, 390.
Based upon specimens in the Ameghino collection purchased by Professor Cope (Cope Pampean Collection, Amer. Mus. Nat. Hist.). The structure forbids reference to Perissodactyla or Artiodactyla and suggests Proboscidean affinities.

.604 Miocene Dogs. *Amer. Nat.* Vol. XV, 1881, p. 497.
May Diagnosis of *Oligobonus* new genus, and revision of diag-
19 nosis of *Hyænocyon* Cope. Corrections and additions to the paper in Bull. Geol. and Geogr. Surveys of the Territories Vol. VI, No. 1, p. 177.

.605 On the Effects of Impacts and Strains on the Feet of Mam-
June malia. *Amer. Nat.* Vol. XV, 1881, pp. 542-548, figs. 1-11.
22 Further discussion of the evolution of the foot construction in various ungulates. Read before the National Academy of Sciences, April, 1881.

.606 [Description and Iconography in Biology.] *Amer. Nat.* Vol.
June XV, 1881, pp. 548, 549.
22 Analytical descriptions cannot be superseded by pictures. Editorial.

.607 Primary Object of an Academy of Science. *Amer. Nat.*
June Vol. XV, 1881, p. 549.
22 Research. Teaching is a collateral activity. Unsigned editorial. Cited by Frazer.

.608 The *Rodentia* of the American Miocene. *Amer. Nat.* Vol.
June XV, 1881, pp. 586, 587.
22 List of 37 species from White River and John Day formations.

.609 A New *Clidastes* from New Jersey. *Amer. Nat.* Vol. XV,
June 1881, pp. 587, 588.
22 Description *C. condon* from a partial skeleton (in Rutgers College).

.610 [Insanity and Responsibility.] *Amer. Nat.* Vol. XV, 1881,
July pp. 641-643.
27 Unsigned editorial. Cited by Frazer.

.611 The Temporary Dentition of a New Creodont. *Amer. Nat.*
July Vol. XV, 1881, pp. 667-669.
27 *Triisodon quivirensis* gen. et sp. nov. based upon a lower jaw from the Puerco formation of New Mexico; and *Delatherium absarokæ* (afterwards type of *Didelphodus*) from Wasatch formation of Bighorn basin, Wyo.

.612 July 27 A Laramie Saurian in the Eocene. *Amer. Nat.* Vol. XV, 1881, pp. 669, 679.
Champosaurus, from Puerco formation of New Mexico.

.613 Sept. 19 Review of the Rodentia of the Miocene Period of North America. *Bull. U. S. Geol. and Geogr. Survey of the Territories* Vol. VI, No. 2, pp. 361-386.

.614 Sept. 19 On the Canidæ of the Loup Fork Epoch. *Bull. U. S. Geol. and Geogr. Survey of the Territories* Vol. VI, No. 2, pp. 387-390.

.615 Sept. 23 [Criticism of Mr. Barn's Metaphysical Definitions.] *Amer. Nat.* Vol. XV, 1881, p. 791.

.616 Sept. 23 Mammalia of the Lowest Eocene. *Amer. Nat.* Vol. XV, 1881, pp. 829-831.
Conoryctes, Catathlæus and *Mioclænus,* new genera, from the Puerco formation. Abstract of 618.

.617 Sept. 23 Geology of the Lake Valley Mining District. *Amer. Nat.* Vol. XV, 1881, pp. 831, 832.

.618 Sept. 30 On some Mammalia of the Lowest Eocene Beds of New Mexico. *Proc. Amer. Philos. Soc.* Vol. XIX, 1881, pp. 484-495. *Pal. Bull.* No. 33, pp. 484-495.
Descriptions of *Periptychus, Conoryctes, Triisodon, Deltatherium, Catathlæus, Anisonchus, Mioclænus*—13 species of these and other genera. Cope does not at this time appear to have been certain whether this fauna was from his Puerco formation or not. "Their horizon is below the Wasatch and they represent a different fauna from that of those beds." See 616 for first notice.

.619 Oct. 28 The Fauna of the Nickajack Cave. (With A. S. Packard, Jr.) *Amer. Nat.* Vol. XV, 1881, pp. 877-882.

.620 Oct. 28 [Rules governing Nomenclature.] *Amer. Nat.* Vol. XV, 1881, pp. 883, 884.
Unsigned editorial. Cited by Frazer. Rules of Internat. Geol. Congress approved, except as to requirement of figure for valid description of new forms. A description is necessary; but that it should be "clear and adequate" is to demand too much.

.621 Oct. 28 A Memoir on the *Loxolophodon* and *Uintatherium,* by Henry F. Osborn, Sc. D. *Amer. Nat.* Vol. XV, 1881, p. 888, 2 figs.
Unsigned review of "A Memoir upon *Loxolophodon* and *Uintatherium,*" etc. Cited by Frazer.

.622 Oct. 28 Eocene Plagiaulacidæ. *Amer. Nat.* Vol. XV, 1881, pp. 921, 922.
Ptilodus mediaevus gen. et sp. nov. described from a tooth from the Puerco formation of New Mexico.

.623 Oct. 28 *Belodon* in New Mexico. *Amer. Nat.* Vol. XV, 1881, pp. 922, 923.
Belodon buceros and *ocolopax* described, the former from a skull.

.624 Dec. [Biology as a Profession.] *Amer. Nat.* Vol. XV, 1881, pp. 987-990.
Unsigned editorial. Cited by Frazer.

.625 Dec. 3 A New Type of *Perissodactyla*. *Amer. Nat.* Vol. XV, 1881, pp. 1017, 1018.
Preliminary description of skeleton of *Phenacodus primaevus* from Bighorn basin (Wasatch) of Wyoming. Condylarthra proposed as a suborder of Perissodactyla.

.626 Dec. 3 New Genus of *Perissodactyla diplarthra*. *Amer. Nat.* Vol. XV, 1881, p. 1018.
Systemodon based upon specimens from Bighorn Wasatch (incorrectly) referred to *Hyrocotherium tapirinum.*

.627 Dec. 3 Notes on *Creodonta*. *Amer. Nat.* Vol. XV, 1881, pp. 1018-1020.
Pachyæna = *Mesonyx; Dissacus,* a new genus, based upon *M. navajovius* of Puerco formation; *Lipodectes* gen. nov. from same horizon, with two species, *penitrans* and *schidens.*

.628 Dec. 3 The Permian Formation of New Mexico. *Amer. Nat.* Vol. XV, 1881, pp. 1020, 1021.
Eryops reticulatus and *Zatrachys apicalis* described; other Permian genera cited as occurring.

.629 Dec. 30 (Legal Insanity.) *Amer. Nat.* Vol. XVI, 1882, pp. 33, 34.
Editorial.

.630 Dec. 30 The Oldest Artiodactyle. *Amer. Nat.* Vol. XVI, 1882, p. 71.
Description of type (jaws, foot, etc.) of *Mioclaenus* (now *Diacodexis*) *brachystomus* from Wasatch of Bighorn basin.

.631 Dec. 30 The Characters of the *Tæniodonta*. *Amer. Nat.* Vol. XVI, 1882, p. 73.
Characters of *Calamodon, Tillotherium* and *Esthonyx* compared.

.632 Dec. 30 New Forms of *Coryphodontidæ*. *Amer. Nat.* Vol. XVI, 1882, p. 72.
Key to genera; two new, *Manteodon* and *Ectacodon.*

.633 Dec. 30 An Anthropomorphous Lemur. *Amer. Nat.* Vol. XVI, 1882, pp. 73, 74.
Notice of cranium of "*Anaptomorphus*" (now *Tetonius*) *homunculus* from Bighorn Wasatch. "The genus is nearer the hypothetical lemuroid ancestor of man than any yet discovered."

.634 Dec. 30 Recent Extinction of the Mastodon. *Amer. Nat.* Vol. XVI, 1882, pp. 74, 75.
Unsigned. Cited by Hay. Preservation of bones, fat and stomach-contents in two Illinois skeletons.

1882.635 Jan. 25 [Science and Art.] *Amer. Nat.* Vol. XVI, 1882, pp. 123, 124.
Unsigned editorial. Cited by Frazer.

.636 Jan. 25 A New Genus of Tillodonta. *Amer. Nat.* Vol. XVI, 1882, pp. 156, 157.
Description of *Psittacotherium multifragum* gen. sp. nov. from Puerco formation of New Mexico.

.637 Jan. 25 A great Deposit of Mud and Lava. *Amer. Nat.* Vol. XVI, 1882, pp. 157, 158.
The Puerco region of N. W. New Mexico.

.638 Jan. 25 Invertebrate Fossils from the Lake Valley District, New Mexico. *Amer. Nat.* Vol. XVI, 1882, pp. 158, 159.
List of Lower Carboniferous fossils, identifications by S. A. Miller.

.639 Feb. 20 Contributions to the History of the Vertebrata of the Lower Eocene of Wyoming and New Mexico, made during 1881. *Proc. Amer. Philos. Soc.* Vol. XX, 1881, pp. 139-197; Map of the Bighorn Basin. *Pal. Bull.* No. 34, pp. 139-197. (Has no map.) Abstract, *Amer. Journ. Sci.*, Ser. 3, Vol. XXIII, 1882, pp. 324-325.
Descriptions of fossil vertebrate collections made by J. L. Wortman for Cope in the Bighorn Basin during the summer of 1881. The descriptions are somewhat amplified and illustrations provided in "Tertiary Vertebrata," 1884. Includes a classification of the Chelonian families and genera, first description of the Eocene lemuroid "*Anaptomorphus homunculus*" skull; classification of Creodonta and description of various new forms; revision of the Coryphodontidae and description of new species; brief synopsis of characters and species of *Phenacodus*; new species of *Hyracotherium*, *Systemodon*, etc.; *Mioclaenus brachystomus* sp. nov. an unquestionable artiodactyl. Fauna is typical Wasatch; distinc-

tions from Wind River fauna. Descriptions of a number of new mammals from the "Catathlaeus beds" of New Mexico (Puerco).

.640 Feb. 24 The Tertiary Formations of the Central Region of the United States. *Amer. Nat.* Vol. XVI, 1882, pp. 177-195, figs. 1-8.

Description of the successive Tertiary "lakes," their location and extent, character of the formations and prominent features of the faunae.

.641 Feb. 24 [The Equivalents of Consciousness.] *Amer. Nat.* Vol. XVI, 1882, pp. 224-226.

Review of essay by E. DuBois Raymond. The Seven World Problems, translated in *Pop. Sci. Mo.* Vol. XX, pp. 433-447.

.642 Feb. 24 Marsh on the Classification of the Dinosauria. *Amer. Nat.* Vol. XVI, 1882, pp. 253-255.

Critical Review of Marsh's article in *Amer. Journ. Sci.* (3) Vol. XXIII, pp. 81-86.

.643 Feb. 24 The Dinosaurs of Bernissart. *Amer. Nat.* Vol. XVI, 1882, pp. 255, 256.

Review of articles by G. A. Boulenger and P. J. Van Beneden. *Bull. Acad. R. de Belge,* 1881, Ser. 3, T. I., pp. 600-608. Unsigned review, evidently Cope's. (W. D. M.)

.644 Feb. 24 Hulke on *Polacanthus foxi.* *Amer. Nat.* Vol. XVI, 1882, p. 256.

Notice of description of this English dinosaur by J. M. Hulke in *Trans. R. Soc. London* Vol. 72, Pt. III, 1881, pp. 653-662, Pls. 70-76. Unsigned. Evidently by Cope. (W. D. M.)

.645 Feb. 24 Russian Sauropterygia. *Amer. Nat.* Vol. XVI, 1882, p. 256.

Notice of memoir on Ichthyosaurus by Kiprijanoff in *Mem. Acad. Imper. Sci. St. Petersbourg,* Ser. 7, T. XXVIII, No. 8.

.646 March 22 [Effort and Use in Evolution.] *Amer. Nat.* Vol. XVI, 1882, pp. 311-313. Editorial.

Further discussion of the views of E. DuBois Raymond.

.647 March 22 New Characters of the *Perissodactyla Condylarthra.* *Amer. Nat.* Vol. XVI, 1882, p. 334.

Creodont characters of humerus in *Phenacodus.* *Meniscotherium* referred to this suborder; key to families.

.648 March 22 *Mesonyx* and *Oxyæna.* *Amer. Nat.* Vol. XVI, 1882, p. 334.

Characters of limb bones in *Mesonyx* (now *Pachyaena*) *ossifragus;* of hind foot in *Oxyæna.* Based on Wortman's Bighorn Wasatch collections.

.649 The Rachitomous Stegocephali. *Amer. Nat.* Vol. XVI, 1882,
March pp. 334, 335.
22 Ganocephala not available. Rhachitomi suborder, including *Eryops, Actinodon, Trimerorhachis, Zatrachys,* etc., in two families.

.650 A Second Genus of Eocene Plagiaulacidæ. *Amer. Nat.* Vol.
April XVI, 1882, pp. 416, 417.
24 *Catopsalis foliatus* gen. et sp. nov. described from Puerco of New Mexico.

.651 Two New Genera of the Puerco Eocene. *Amer. Nat.* Vol.
April XVI, 1882, pp. 417, 418.
24 Description of *Haploconus lineatus* and *Pantolambda bathmodon* new genera and species.

.652 On Archæsthetism. *Amer. Nat.* Vol. XVI, 1882, pp. 454-469.
May Discussion of the origin of adaptive changes in phyla;
20 the nature of consciousness and its relations thereto, as a fundamental cause of evolution.

.653 [Sexual Selection in Man.] *Amer. Nat.* Vol. XVI, 1882,
May pp. 490-492.
20 Editorial.

.654 The Ancestry and Habits of *Thylacoleo.* *Amer. Nat.* Vol.
May XVI, 1882, pp. 520-522.
20 Thylacoles, a descendant of the *Plagiaulacidæ.* *Hypriprymus* parallel not nearly related. Probably not herbivorous, perhaps egg-eating or even carnivorous.

.655 Notes on Eocene Mammalia. *Amer. Nat.* Vol. XVI, 1882,
May p. 522.
20 *Didelphodus* and *Ectocion* new genera, Wasatch Eocene Bighorn basin.

.656 On the *Taxæopoda,* a New Order of *Mammalia.* *Amer.*
May *Nat.* Vol. XVI, 1882, pp. 522, 523.
20 Carpus of *Phenacodus* excludes it from Perissodactyla. The new order includes Condylarthra and Proboscidea. Key to Ungulate orders.

.657 [Note on *Achænodon insolenus.*] *Amer. Nat.* Vol. XVI, 1882,
May p. 534.
20 Notice of discovery of skull by Princeton Expedition.

.658 On the *Condylarthra.* *Proc. Acad. Nat. Sci. Phila.* Vol.
June XXXIV, 1882, pp. 95-97. Reprint, *Ann. & Mag. Nat. Hist.*,
6 Ser. 5, Vol. X, 1882, pp. 76-79.

.659 June 22 A New Genus of Tæniodonta. *Amer. Nat.* Vol. XVI, 1882, pp. 604, 605.
Tæniolabis sulcatus gen. et sp. nov., based upon an incisor tooth from the Puerco of New Mexico. Unsigned. Cited by Hay and Frazer.

.660 July 28 [The Philadelphia Academy of Natural Sciences.] *Amer. Nat.* Vol. XVI, 1882, pp. 663, 664.
Unsigned editorial. Cited by Frazer.

.661 July 28 New Marsupials from the Puerco Eocene. *Amer. Nat.* Vol. XVI, 1882, pp. 684-686.
Descriptions of *Polymastodon taöensis* and *Catopsalis pollux* new genera and species. (These subsequently proved to be founded upon the upper and lower dentition of the same individual. Both are probably identical with *Taeniolabis sulcatus.*) New species of *Ptilodus* and *Haploconus* also described; all from Puerco formation of New Mexico.

.662 Sept. 28 [Projects for Commemorating Men of Science.] *Amer. Nat.* Vol. XVI, 1882, pp. 803, 804.
Unsigned editorial. Cited by Frazer.

.663 Sept. 28 Mammalia in the Laramie Formation. *Amer. Nat.* Vol. XVI, 1882, pp. 830, 831.
Description of *Meniscœssus conquistus* gen. et sp. nov. (from the Lance formation).

.664 Sept. 28 A New Form of Tæniodonta. *Amer. Nat.* Vol. XVI, 1882, pp. 831, 832.
Hemiganus vultuosus (=*Psittacotherium*) from Puerco of New Mexico.

.665 Sept. 28 The *Periptychidæ*. *Amer. Nat.* Vol. XVI, 1882, pp. 832, 833.
Structure of brain and foot, etc., in *Periptychus;* description of *Hemithlæus kowalevskianus* gen. et sp. nov., etc.

.666 Sept. 28 Some New Forms from the Puerco Eocene. *Amer. Nat.* Vol. XVI, 1882, pp. 833, 834.
New species of *Mioclænus, Protogonia* and *Dissacus.*

.667 Oct. 28 [Remarks on Guiteau's Brain.] *Amer. Nat.* Vol. XVI, 1882, pp. 895, 896.
Unsigned editorial. Cited by Frazer.

.668 Oct. 28 [Note on the Bite of a Gila Monster.] *Amer. Nat.* Vol. XVI, 1882, pp. 908, 909.

.669 Oct. 28 The Recent Discoveries of Fossil Footprints in Carson, Nevada. *Amer. Nat.* Vol. XVI, 1882, pp. 921-923.
Unsigned. Cited by Hay. Notice of paper by Le Conte read before the California Academy of Sciences.

.670 Oct. 28 Geological News. *Amer. Nat.* Vol. XVI, 1882, pp. 925, 926.
Brief notices of papers by Scudder, *Amer. Journ. Sci.* (3) Vol. XXIV, pp. 161-170; McGee and Call, Ibid, pp. 202-223; Scott and Osborn, Ibid, pp. 223-225. Unsigned. Cited by Hay.

.671 Nov. 11 The Classification of the Ungulate Mammalia. *Proc. Amer. Philos. Soc.* Vol. XX, 1882, pp. 438-447. *Pal. Bull.* No. 35, pp. 438-447. Abstract, *Science* Vol. I, 1883, p. 182.
Construction of carpus and tarsus is fundamental to the ordinal classification. Relations of carpals and tarsals in different groups of ungulates; key to orders; phylogeny.

.672 Nov. 11 Third Contribution to the History of the Vertebrata of the Permian Formation of Texas. *Proc. Amer. Philos. Soc.* Vol. XX, 1882, pp. 447-461. *Pal. Bull.* No. 35, pp. 447-461. Abstract, "Permian Vertebrata," *Amer. Nat.* Vol. XVI, 1882, p. 925.
Descriptions of *Edaphosaurus, Ectocynodon, Diplocaulus, Acheloma, Anisodexis,* the first and last two new genera.

.673 Nov. 11 Synopsis of the Vertebrata of the Puerco Eocene Epoch. *Proc. Amer. Philos. Soc.* Vol. XX, 1882, pp. 461-471. *Pal. Bull.* No. 35, pp. 461-471.
List of vertebrata, chiefly mammals; descriptions of a number of new species; relations of the fauna.

.674 Nov. 11 On the Systematic Relations of the *Carnivora* Fissipedia. *Proc. Amer. Philos. Soc.* Vol. XX, 1882, pp. 471-475. *Pal. Bull.* No. 35, pp. 471-475. Reprint, *Ann. & Mag. Nat. Hist.*, Ser. 5 Vol. XII, 1883, pp. 112-116.
Classification, based primarily upon the turbinal bones, then upon teeth, alisphenoid, etc.; list of genera of each family. *Plethælurus* gen. nov. for *Felis planiceps.*

.675 Dec. 2 The Reptiles of the American Eocene. *Amer. Nat.* Vol. XVI, 1882, pp. 979-993, figs. 11-13.
Review of Eocene reptilian fauna; figures of *Palacophis* vertebræ; skulls of 3 species of Crocodiles, several turtles.

.676 Dec. 2 [Women in Universities.] *Amer. Nat.* Vol. XVI, 1882, pp. 994, 995.
Unsigned editorial. Cited by Frazer.

.677 Dec. 2 Two New Genera of Mammalia from the Wasatch Eocene. *Amer. Nat.* Vol. XVI, 1882, p. 1029.
Diacodexis and *Heptodon,* new genera, from the Bighorn basin.

.678 Dec. 2 Restoration of *Loxolophodon cornutus* Cope, one-twentieth natural size. From the Bridger Eocene of Wyoming. *Amer. Nat.* Vol. XVI, 1882, Pl. XVII (no text).
Reduced from drawing afterwards published in "Tertiary Vertebrata."

1883.679 On the contents of a Bone Cave in the Island of Anguilla (West Indies). *Smithsonian Contrib. to Knowledge* Vol. XXV, Art. 3, pp. 1-34, Pls. I-V. Separates 1883.
Extended description and illustrations of *Amblyrhiza*, etc.

.680 The Classification of the Ungulata. *Proc. A. A. A. S.* XXXI Meeting, 1882, pp. 477-479.

.681 The Fauna of the Puerco Eocene. *Proc. A. A. A. S.* XXXI Meeting, 1882, pp. 479, 480.

.682 Jan. 5 The Nevada Biped Tracks. *Amer. Nat.* Vol. XVII, 1883, pp. 69, 70, three figures.
Remarks with figures from Harkness' paper before Calif. Acad. Sci. Supposed to be a reprint of 689, but in reality appearing first. The cuts are not in the Proc. Acad. Nat. Sci. Phila.

.683 Jan. 5 On *Uintatherium* and *Bathmodon*. *Amer. Nat.* Vol. XVII, 1883, p. 68.
Distinctions in incisors between *Uintatherium* and *Bathyopsis;* in astragalus between *Coryphodon* and *Bathmodon.* Intended as an abstract of 690.

.684 Jan. 5 The Extinct Rodentia of North America. *Amer. Nat.* Vol. XVII, 1883, pp. 43-57; 165-174; 370-381; figs. 1-30.
Key to classification, geological distribution, review of genera and species with figures of many specimens from Wasatch and Bridger, White River and John Day; afterwards published in extenso in "Tertiary Vertebrata." The groups of pages appeared successively on January 5th and 31st, and March 15.

.685 Jan. 5 [The National Academy of Sciences.] *Amer. Nat.* Vol. XVII, 1883, pp. 59, 60.
Unsigned editorial. Cited by Frazer.

.686 Jan. 5 Kowalevsky on *Elasmotherium*. *Amer. Nat.* Vol. XVII, 1883, p. 72.
Notice of Kowalevsky's memoir.

.687 Jan. 5 Two New Genera of Pythonomorpha. *Amer. Nat.* Vol. XVII, 1883, pp. 72, 73.
Comment on Dollo's paper, "Note sur l'osteologie des

Mosasauridæ," Bull. Mus. Roy. d'hist. nat. de Belgique, T. I., pp. 1-20, Pls. IV, V et VI.

.688 Jan. 5 Scudder on Triassaic Insects. *Amer. Nat.* Vol. XVII, 1883, p. 73.

Note on the age of the Red Beds near Fairplay, Colorado.

.689 Jan. 16 (Contemporaneity of Man and Pliocene Mammals). *Proc. Acad. Nat. Sci., Phila.* Vol. XXXIV, 1882, pp. 291, 292.

See also 682 and note. Later discussion 746.

.690 Jan. 16 On *Uintatherium*, *Bathmodon* and *Triisodon*. *Proc. Acad. Nat. Sci Phila.* Vol. XXXIV, 1882, pp. 294-300.

For abstract see 683 and note.

.691 Jan. 31 (The Beastiarians). *Amer. Nat.* Vol. XVII, 1883, p. 175.

Criticism of antivivisectionist activities. Unsigned editorial. Cited by Frazer.

.692 Jan. 31 Filhol's Fossil Mammals of Ronzon. *Amer. Nat.* Vol. XVII, 1883, pp. 190, 191.

Review of "Etude des Mammiferes fossiles de Ronzon (Haute Loire)," by M. H. Filhol.

.693 Jan. 31 New Mammalia from the Puerco Eocene. *Amer. Nat.* Vol. XVII, 1883, p. 191.

Helagras prisciformis gen. et sp. nov.; *Pantolestes* provisionally placed in Artiodactyla with species "*Mioclaenus*" *brachystomus* and *etsagicus* referred to it. No other tenable description of new forms. Abstract of 695.

.694 Feb. 9 Zoölogical Geography of Western North America. *Science* Vol. I, No. 1, February 9, 1883, p. 21.

Abstract of 697.

.695 Feb. 14 First Addition to the Fauna of the Puerco Eocene. *Proc. Amer. Philos. Soc.* Vol. XX, 1883, pp. 545-563. *Pal. Bull.* No. 36, pp. 545-563.

In the full paper appears an extended description of "*Mioclænus*" *ferox* (= *Clænodon*), compared here with carnivorous marsupials (a view subsequently withdrawn by Professor Cope); of skeleton of *Pantolambda* for which a new suborder of Amblypoda, Taligrada, is erected; of various new species, etc.; the Puerco mammals nearly all have tritubercular molars, quadritubercular molar derived from this type. For description of *Pantolambda* see 702 and note. Also see note on dates of publication of the various pages of this article. In the Proc. Amer. Philos. Soc., pp. 545-554 were printed February 14, 555-563 on March 16. Bull. published April 17. For abstract see 693.

.696 Phylogeny of the Sirenia. *Science* Vol. I, No. 2, February
Feb. 16, 1883, p. 53.
16 Abstract of 706.

.697 Notes on the Geographical Distribution of Batrachia and
Feb. Reptilia in Western North America. *Proc. Acad. Nat. Sci.*
20 *Phila.* Vol. XXXV, 1883, pp. 10-35.
See 694.

.698 On the Extinct Dogs of North America. *Amer. Nat.* Vol.
Feb. XVII, 1883, pp. 235-249, figs. 1-14.
21 Key to extinct American genera; descriptions with figures of principal forms from John Day and Loup Fork (some figures afterwards in "Tertiary Vertebrata," others in "Unpublished Plates of Tertiary Vertebrata"). Phylogeny and origin.

.699 [Credit and Appropriation.] *Amer. Nat.* Vol. XVII, 1883,
Feb. pp. 293, 294.
21 Unsigned editorial. Cited by Frazer.

.700 A New Fossil Sirenian. *Amer. Nat.* Vol. XVII, 1883, p. 309.
Feb. *Dioplotherium manigaulti* nov. gen. et sp. from Miocene
21 of S. Carolina. Abstract of 706 as is also 696.

.701 Lydekker on Indian Mammalia. *Amer. Nat.* Vol. XVII,
March 1883, pp. 405, 406.
15 Critical review of *Pal. Indica,* Vol. III, Pts. I and III.

.702 The Ancestor of *Coryphodon.* *Amer. Nat.* Vol. XVII, 1883,
March pp. 406, 407.
15 Skeleton characters of *Pantolambda;* referred to Amblypoda new suborder; Taligrada, family Pantolambdidæ. Antedates by one day the pages of 695 dealing with this genus.

.703 On the Brains of the Eocene Mammalia *Phenacodus* and
March *Periptychus.* *Proc. Amer. Philos. Soc.* Vol. XX, 1883, pp.
16 563-565, Pls. I, II. *Pal. Bull.* No. 36, pp. 563-565, Pls. I, II.
In *Phenacodus* cerebrum remarkably small; sylvian fissure and traces of 3 convolutions present; cerebellum with distinct vermis and large lateral lobes. Olfactory lobes large, well separated. In *Periptychus* olfactory lobes enormous, mesencephalon wholly exposed, no sylvian fissure.

.704 *Dimodipsas,* a New Venomous Snake. *Science* Vol. I, No. 7,
March March 23, 1883, p. 204.
23 From South America. See 710.

.705 Permian Fishes and Reptiles from Texas. *Science* Vol. I,
March No. 7, March 23, 1883, p. 204.
23 Supposed to be a reprint of Proc. Acad. Nat. Sci. Phila., but in reality published first. See 711.

.706 March 27 On a New Extinct Genus of Sirenia from South Carolina. *Proc. Acad. Nat. Sci. Phila.* Vol. XXXV, 1883, pp. 52-54.
For abstract see 696 and 700.

.707 March 27 The Tritubercular Type of Superior Molar Tooth. *Proc. Acad. Nat. Sci. Phila.* Vol. XXXV, 1883, p. 56. Reprinted, "Note on the Trituberculate Type of Superior Molar and the Origin of the Quadrituberculate," *Amer. Nat.* Vol. XVII, 1883, pp. 407, 408.
The quadritubercular molar type derived from it. Predominant in Puerco Eocene.

.708 March 30 Permian Reptiles. *Science* Vol. I, No. 8, March 30, 1883, p. 232.
Supposed to be a verbal communication at the Acad. Nat. Sci. Phila., March 13, 1883, but not to be found in the Proceedings.

.709 April 4 Fourth Contribution to the History of the Permian Formation of Texas. *Proc. Amer. Philos. Soc.* Vol. XX, 1883, pp. 628-636. *Pal. Bull.* No. 36, pp. 628-636.
Ectosteorhachis, Gnathorhija gen. nov., *Chilonyx* gen. nov., and new species of *Empedias: Pariotichus megalops. Pariotichus-Pantylus-Ectocynodon* = new family *Pariotichidæ.*

.710 April 10 On *Dinodipsas* and *Causus. Proc. Acad. Nat. Sci. Phila.* Vol. XXXV, 1883, p. 57.
For abstract see 704.

.711 April 10 Permian Fishes and Reptiles. *Proc. Acad. Nat. Sci. Phila.* Vol. XXXV, 1883, p. 69. Abstract, *Amer. Nat.* Vol. XVII, 1883, p. 905.
See also 705.

.712 April 18 [Scientific Publications of the United States Government.] *Amer. Nat.* Vol. XVII, 1883, pp. 515, 516.
Unsigned editorial. Cited by Frazer.

.713 April 18 The Genus *Phenacodus. Amer. Nat.* Vol. XVII, 1883, p. 535, Pl. XII.
General characters, with figure, of skeleton found by Wortman in Bighorn basin of Wyoming; list of species of the genus.

.714 May 4 Geology of Brazil. *Science* Vol. I, No. 13, May 4, 1883, pp. 367, 368.
This is supposed to be part of the Proc. Acad. Nat. Sci. Phila. for April 10, but is not in the volume for 1883.

.715 May 4 The bunotherian Mammalia. *Science* Vol. I, No. 13, May 4, 1883, p. 372.
An abstract of 718 but first to be printed.

.716 The Developmental Significance of Human Physiography.
May *Amer. Nat.* Vol. XVII, 1883, pp. 618-627, Pls. XIII-XV,
17 figs. 1-9.

.717 [The National Academy of Sciences.] *Amer. Nat.* Vol.
May XVII, 1883, pp. 627, 628.
17 Unsigned editorial.

.718 On the Mutual Relations of the Bunotherian Mammalia.
May *Proc. Acad. Nat. Sci. Phila.* Vol. XXXV, 1883, pp. 77-83.
22 Reprint, *Ann. & Mag. Hist.*, Ser. 5, Vol. XII, 1883, pp. 20-26.
For abstract see 715.

.719 Characters of the Hadrosauridæ. *Science* Vol. I, No. 16,
May May 25, 1883, p. 468.
25 Intended as an abstract of 721 but printed first.

.720 On a New Extinct Genus and Species of Percidæ from
June Dakota Territory. *Amer. Journ. Sci.* Ser. 3, Vol. XXV,
1883, pp. 414-416.
Plioparchus Nov. Gen., and *P. whitei and P. sexspinosus* N. Sp.

.721 On the Characters of the Skull of the Hadrosauridæ. *Proc.
June Acad. Nat. Sci. Phila.* Vol. XXXV, 1883, pp. 97-107, Pls.
5 IV-VII. Abstract, "The Structure and Appearance of a Laramie Dinosaurian." *Amer. Nat.* Vol. XVII, 1883, pp. 774-777, Pls. XVI-XIX, & pp. 1000, 1001.
See also 719.

.722 The Unification of Geological Nomenclature and Cartog-
June raphy. *Amer. Nat.* Vol. XVII, 1883, pp. 764, 765.
20 Unsigned editorial. Cited by Frazer.

.723 On some Vertebrata from the Permian of Illinois. *Proc.
June Acad. Nat. Sci. Phila.* Vol. XXXV, 1883, pp. 108-110.
26 *Thoracodus emydinus* Nov. Gen. et Sp., and *Ctenodus heterolophus* and *C. vasabinsis* N. Sp.

.724 Puerco Beds in France. *Science* Vol. II, No. 22, July 6,
July 1883, p. 20.
6 Supposed to be a verbal communication at the Academy of

.725 A New Hydroid Polyp. *Science* Vol. II, No. 22, July 6,
July 1883, p. 22.
6 In reality one paragraph of 732, p. 140. It appeared before the entire article, however.

.726 Extinct fauna of Idaho and Oregon. *Science* Vol. II, No.
July 23, July 13, 1883, p. 56.
13 An abstract of 732 but published before the article.

.727 July 16 Late Works on Evolution. *Amer. Nat.* Vol. XVII, 1883, pp. 855-858.

Review of: The Theories of Darwin and Their Relation to Philosophy, Religion and Morality, by Rudolf Schmid; Final Causes, by Paul Janet; A Critique of Design-arguments, etc., by L. E. Hicks; Development, what it can do and what it cannot do, by James McCosh; Natural Selection and Natural Theology, a discussion between Dr. Romanes and Dr. Asa Gray, *Nature* Vol. XXVI, 1883.

.728 July 16 A New Pliocene Formation in the Snake River Valley. *Amer. Nat.* Vol. XVII, 1883, pp. 867, 868.

Willow Creek, in Eastern Oregon.

.729 July 16 The "Third Trochanter" of the Dinosaurs. *Amer. Nat.* Vol. XVII, 1883, p. 869.

Unsigned. Cited by Hay. A summary of Dollo's article in *Bull. Mus. R. Hist. Nat. Belg.* T. I. Mars, pp. 13-18, Pl. I.

.730 July 16 The Puerco Fauna in France. *Amer. Nat.* Vol. XVII, 1883, pp. 869, 870.

A critical summary of Lemoine's "Recherches sur les oisseaux fossils des terrains tertiares inférieurs des environs de Reims." Part II. For abstract see 724.

.731 July 24 The Fishes of the Batsto River, New Jersey. *Proc. Acad. Nat. Sci. Phila.* Vol. XXXV, 1883, pp. 132, 133. Abstract, *Science* Vol. II, No. 26, p. 149.

Eleven species listed and *Amiurus prosthistius* N. Sp. described.

.732 Aug. 7 On the Fishes of the Recent and Pliocene Lakes of the Western Part of the Great Basin, and of the Idaho Pliocene Lake. *Proc. Acad. Nat. Sci. Phila.* Vol. XXXV, 1883, pp. 134-166 and Map. Abstract, "Fossil Fishes from Idaho," *Amer. Nat.* Vol. XVII, 1883, p. 1321.

Faunal list with descriptions of fishes of this region including descriptions of 6 new species of recent fishes and 9 new species out of 22 fossil forms. For an earlier published abstract see 725 and 726.

.733 Aug. 15 The Evolutionary Significance of Human Character. *Amer. Nat.* Vol. XVII, 1883, pp. 907-919.

A continuation of 716.

.871 Aug. 15 Jordan's Catalogue of Fishes of North America. *Amer. Nat.* XVII, 1883, p. 967.

Review of anniversary address to the Geol. Soc. London. Unsigned. Given on Dr. Matthew's authority.

.735 Some New Mammalia of the Puerco Formation. *Amer. Nat.*
Aug. Vol. XVII, 1883. p. 968.
15 Additional remains of *Periptychus ditrigonus* show that it belongs to *Conoryctes,* probably family Periptychidæ. Three new species named, genus *Zetodon* (new) defined. Unsigned. Given on Dr. Matthew's authority. See 741.

.736 Geological Notes. *Amer. Nat.* Vol. XVII, 1883, pp. 968, 970.
Aug. Notices of various new publications chiefly on vertebrate
15 palaeontology. Unsigned. Cited by Hay.

.737 The Evidence for Evolution in the History of the Extinct
Aug. Mammalia. *Science* Vol. II, 1883, pp. 272-279. Reprint,
31 *Nature* Vol. XXIX, 1884, pp. 227-230; 248-250. Reprint, *Proc. A. A. A. S.,* XXXII Meeting, 1883, pp. 32-48. Abstract, "Progress of the Ungulates in Tertiary Time," *Amer. Nat.* Vol. XVII, 1883, pp. 1055-1057.

The paper was originally read before the A. A. A. S. but not printed in the proceedings (see the second reprint) until 1884.

.738 The Structure of the Skull in *Diclonius mirabilis,* a Laramie
Sept. Dinosaurian. *Science* Vol. II, 1883, p. 338. *Proc. A. A. A. S.,* XXXII Meeting, 1883, pp. 315, 316.

Abstract only of paper read before the A. A. A. S. For other papers on *Diclonius* see 719, 721.

.739 Two primitive Types of Ungulata. *Science* Vol. II, 1883,
Sept. p. 338. Abstract, "On two primitive types of Ungulatæ,"
7 *Proc. A. A. A. S.,* XXXII Meeting, 1883, p. 316.

Abstracts of a paper read before the A. A. A. S. but not printed in the proceedings until 1884.

.740 The Trituberculate Type of Superior Molar, and the Origin
Sept. of the Quadrituberculate. *Science* Vol. II, 1883, September
7 7, p. 338.

Abstract of 760. See also 707.

.741 On some Fossils of the Puerco Formation. *Proc. Acad.*
Sept. *Nat. Sci. Phila.* Vol. XXXV, 1883, pp. 168-170. Abstract,
18 "Some New Mammalia of the Puerco Formation," *Amer. Nat.* Vol. XVII, 1883, p. 968.

See 735. Probably an abstract.

.742 Weismann's Studies in the Theory of Descent. *Amer. Nat.*
Oct. Vol. XVII, 1883, pp. 1042-1046.

Unsigned. Cited by Frazer. Review of: Studies in the Theory of Descent, by Dr. August Weismann. Translated and edited, with notes by Raphael Meldola, etc.

.743 Oct. Geological Notes. *Amer. Nat.* Vol. XVII, 1883, pp. 1057, 1058.

Notices of various papers chiefly on vertebrate palaeontology. Unsigned. Cited on Dr. Matthew's authority.

.744 Oct. 19 [The Work of the Mutual Autopical Society.] *Amer. Nat.* Vol. XVII, 1883, pp. 1138, 1139.

Unsigned editorial. Cited by Frazer.

.745 Oct. 19 A new Chrondrostean from the Eocene. *Amer. Nat.* Vol. XVII, 1883, pp. 1152, 1153.

Crassopholis magnicaudatus gen. et sp. nov. from Green River formation of Wyoming.

.746 Oct. 19 The Carson Footprints. *Amer. Nat.* Vol. XVII, 1883, p. 1153.

For earlier discussions see 682 and 689.

.747 Oct. 30 Letter from Little Missouri, Dakota. *Proc. Amer. Philos. Soc.* Vol. XXI, 1883, pp. 216, 217. Reprinted, *Pal. Bull.* No. 37, pp. 216, 217, as "On a New Basin of White River Age in Dakota."

Geological notes, list of species of fossil vertebrates.

.748 Nov. 28 [Government Aid to Science.] *Amer. Nat.* Vol. XVII, 1883, pp. 1258, 1259.

Unsigned editorial.

.749 Nov. 28 A New Snake from Mexico. *Amer. Nat.* Vol. XVII, 1883, pp. 1300, 1301.

Atomarchus multimaculatus.

.750 Nov. 28 The Laramie Formation. *Amer. Nat.* Vol. XVII, 1883, p. 1320.

Supposedly an abstract of the meeting of the Acad. Nat. Sci. Phila. on June 12. No such communication by Cope is recorded in the proceedings.

.751 Dec. 29 The Batrachia of the Permian Period of North America. *Amer. Nat.* Vol. XVIII, 1884, pp. 26-39, Pls. II-V, figs. 1-7.

Classification, phylogeny of the groups, review of principal American Permian genera with illustrations; discussion of vertebral construction.

.752 Dec. 29 Mechanical Evolution. *Amer. Nat.* Vol. XVII, 1884, pp. 40, 41.

Editorial on Darwin's "Origin of Species."

.753 Dec. 29 The Loup Fork Beds on the Gila River. *Amer. Nat.* Vol. XVIII, 1884, pp. 58, 59.

Abstract of 758. Description of the formation. Age determined by a skull of *Aphelops fossiger* Cope.

754 Dec. 29 On New Lemuroids from the Puerco Formation. *Amer. Nat.* Vol. XVIII, 1884, pp. 59-62.

Key to classification. *Tricentes* and *Indrodon* new genera described.

884.755 The Vertebrata of the Tertiary Formations of the West. Book I. *Report, U. S. Geol. Survey of the Territories* (Hayden). Vol. III, pp. i-xxxv, 1-1009, Pls. I-LXXVa.

This volume contains only the first half of Cope's final report to the Hayden Survey upon the Tertiary Mammalia. It includes the Eocene faunas and a part of the Oligocene (Lower Miocene) Rodentia and Insectivora, etc., Carnivora. The second half, to include the Oligocene ("Lower Miocene") Ungulata and the Miocene ("Loup Fork") fauna, was never published, although a large part of the plates were made and printed. (See 1395.) Forty-two fishes are described, belonging to eleven genera, and are shown in 185 figures on 14 plates.

.756 An Account of the Mammalian Fauna of the Post-pliocene Deposits in the State of Indiana. (With J. L. Wortman.) *Fourteenth Ann. Report* (Dept. Geol. and Nat. Hist.), *Survey of Indiana,* John Collet, State Geologist, Pt. II, Palaeontology, 1884, pp. 1-41, Pls. I-VI.

.757 Genus *Equus. Fourteenth Ann. Report* (Dept. Geol. and Nat. Hist.), *Survey of Indiana,* John Collet, State Geologist, Pt. II, Palaeontology, 1884, pp. 40, 41. Appendix to 756.

.758 Jan. 2 On the Distribution of the Loup Fork Formation in New Mexico. *Proc. Amer. Philos. Soc.* Vol. XXI, 1883, pp. 308, 309. *Pal. Bull.* No. 37, pp. 308, 309.

For abstract see 753. Headwaters of Gila R. and San Francisco about 500 feet thickness. Also probably along eastern base of Magdalena mountains.

.759 Jan. 2 Second Addition to the Knowledge of the Puerco Epoch. *Proc. Amer. Philos. Soc.* Vol. XXI, 1883, pp. 309-324. *Pal. Bull.* No. 37, pp. 309-324.

Several new species described; extended description of *Tricentes* and *Indrodon; Chirox* described as new genus; synopsis of the Eocene lemuroid genera; characters of the fauna—tritubercular bunodont teeth and plantigrade pentadactyl feet.

.760 Jan. 2 On the Trituberculate Type of Molar Tooth in the Mammalia. *Proc. Amer. Philos. Soc.* Vol. XXI, 1883, pp. 324-326. *Pal. Bull.* No. 37, pp. 324-326. *Proc. A. A. A. S.* XXXII Meeting, 1883, pp. 313-315.

Viewed as the primitive type from which are derived the later types of mammalian molars. Of these papers the Pal. Bull. was the first to be issued, its pagination being, as usual, that of the Philos. Soc. Both these differ in only the minutest detail from the Proc. A. A. A. S., so that it seems inadvisable to regard that, published in 1884 also as a separate article. For abstract see 740.

.761 [The Society of Naturalists of the Eastern United States.]
Jan. *Amer. Nat.* Vol. XVIII, 1884, pp. 160, 161.
21 Unsigned editorial. Cited by Frazer.

.762 Mission Scientifique au Mexique; Recherches zoologiques;
Jan. Trois. Partie, Rech. sur les Reptiles et les Batrachiens, par
21 MM. Duméril et Bocourt. *Amer. Nat.* Vol. XVIII, 1884, pp. 162, 163.
Review.

.763 Results of the Deep-sea Work of the "Talisman." *Amer.*
Jan. *Nat.* Vol. XXVIII, 1884, p. 177.
21

.764 On Extinct Rhinoceri from the Southwest. *Proc. Acad.*
Jan. *Nat. Sci. Phila.* Vol. XXXV, 1883, p. 301.
29

.765 The History of the Oreodontidæ. *Amer. Nat.* Vol. XVIII,
Feb. 1884, pp. 280-282.
17 Abstract of 786, printed before the article. Review of the genera and list of species with phyletic relations and geologic occurrence.

.766 The Creodonta. *Amer. Nat.* Vol. XVIII, 1884, pp. 255-267;
Feb. 344-353; 478-485, figs. 1-30.
17 Affinities, classification, review of principal known genera with illustrations. The discussion of the affinities of the Creodonta with Marsupials, Insectivora, etc., is an admirable example of sound reasoning in comparative anatomy, and of clear and condensed presentation of the salient points of the evidence then available. The pages appeared successively in the March (published Feb. 17), April (published March 15), and May (published April 19) numbers of the Amer. Nat.

.767 [The Law and Insanity.] *Amer. Nat.* Vol. XVIII, 1884,
Feb. pp. 267-269.
17 Editorial.

.768 Professor Owen on Fossil Mammals. *Amer. Nat.* Vol.
Feb. XVIII, 1884, p. 283.
17 Unsigned but in the index of the volume under Cope. Notice of Owen's descriptions of *Sceparnodon* from the Pleis-

tocene of Australia (*Philos. Trans.*, Pt. 1, pp. 245-248, Pl. 12), and *Tritylodon* from the Trias of South Africa (*Quart. Journ. Geol. Soc.*, London, Vol. XL, pp. 146-156, Pl. VI). The latter is allied to *Meniscoessus* and *Polymastodon*.

.769 Feb. 17 — Filhol on Eocene Lemuroids. *Amer. Nat.* Vol. XVIII, 1884, p. 283.
Note upon supposed identity of *Anaptomorphus* with *Necrolemur* and of *Notharctus* with *Adapis*. Filhol's paper, *Ann. Sci. géol.* Vol. 14.

.770 Feb. 17 — The Diseases of the Will. *Amer. Nat.* Vol. XVIII, 1884, pp. 317, 318.
Review of: Diseases of the Will, by Th. Ribot; Humboldt Library No. 52.

.771 March 7 — A Carboniferous Genus of Sharks still living. *Science* Vol. III, No. 57, March 7, 1884, pp. 275, 276.
Chlamydoselachus-Didymodus. See also 773, 782 and 792.

.772 March 15 — [Natural Science in Philadelphia.] *Amer. Nat.* Vol. XVIII, 1884, pp. 393-395.
Unsigned editorial. Cited by Frazer.

.773 March 15 — The Skull of a Still Living Shark of the Coal Measures. *Amer. Nat.* Vol XVIII, 1884, pp. 412, 413.
See 771 for the first note on *Didymodus*.

.774 April 19 — Philadelphia Academy. *Amer. Nat.* Vol. XVIII, 1884, pp. 510, 511.
Unsigned editorial. Under Cope in volume index.

.775 April 19 — Garman's North American Reptiles and Batrachians. *Amer. Nat.* Vol. XVIII, 1884, pp. 513-515.
Review of: A List of the Species occurring North of the Isthmus of Tehuantepec, with references. From the Bulletin, Essex Institute, Salem, Jan. 1884. On the Reptiles and Batrachians [of the Kentucky Geological Survey]. From Memoirs, Museum of Comparative Zoölogy, Cambridge, 4to. (no date). Unsigned. Cited by Frazer.

.776 April 19 — The Mastodons of North America. *Amer. Nat.* Vol. XVIII, 1884, pp. 524-526. Abstract ("Different Species of Mastodons,") *Science* Vol. III, No. 65, May 2, 1884, pp. 553, 554.
Key to the American species; description of new forms. The abstract is supposed to be a verbal communication before the Acad. Nat. Sci. Phila., March 22, but is not recorded in the Proceedings.

.777 Marsh on Diplodocus. *Amer. Nat.* Vol. XVIII, 1884,
April p. 526.
19 Critical notice of Marsh's paper in *Amer. Journ. Sci.*

.778 The Pelvisternum of Edentates. *Amer. Nat.* Vol. XVIII,
May 1884, pp. 639, 640.
17 Review of Albrecht's paper. Unsigned. Cited by Hay.

.779 The Practical Type of Mind. *Amer. Nat.* Vol. XVIII,
May 1884, p. 644.
17

.780 The Tertiary Marsupialia. *Amer. Nat.* Vol. XVIII, 1884,
May pp. 686-697, figs. 1-9.
17 Didelphidæ and Multituberculata. Classification of Multituberculates, description of principal forms with illustrations; phylogeny.

.781 [Note on the Collections in the Muséo Nacional.] *Proc.*
May *Amer. Philos. Soc.* Vol. XXI, 1884, p. 487.
29

.782 *Pleuracanthus* and *Didymodus*. *Science* Vol. III, No. 69,
May May 30, 1884, pp. 645, 646.
30 See also 771 and 792.

.783 [Zoology in the National Parks.] *Amer. Nat.* Vol. XVIII,
June 1884, pp. 708, 709.
17 Unsigned editorial. Cited by Frazer.

.784 Lydekker on Extinct Mammalia of India. *Amer. Nat.* Vol.
June XVIII, 1884, pp. 717, 718.
17 Critical review of: Memoirs, Geological Survey of India, Ser. X, Vol. II, Siwalik Camelopardalidæ, and Siwalik and Narbada Carnivora (Parts IV and VI); Vol. III Additional Perissodactyla and Proboscidia (Part I).

.785 Notes on Abnormal Deer Antlers. *Amer. Nat.* Vol. XVIII,
June 1884, pp. 737, 738.
17 Editorial note on communication by J. D. Caton.

.786 Synopsis of the Species of Oreodontidæ. *Proc. Amer. Philos.*
July *Soc.* Vol. XXI, 1884, pp. 503-572, two figs. *Pal. Bull.* No. 38,
1 pp. 503-572, two figs.

Synopsis of family characters and affinities, key to genera; principal characters of each genus, diagnoses and synonymy of species in each. Fifteen new species or subspecies described and extended or revised descriptions of a number of others. Affinities of genera, geological distribution. For abstract see 765.

.787 July 17 On the Structure of the Skull in the Elasmobranch Genus *Didymodus*. *Proc. Amer. Philos. Soc.* Vol. XXI, 1884, pp. 572-590, one plate. *Pal. Bull.* No. 38, pp. 572-590, one plate.

Description of partial skull in Cope Collection from Permian of Texas.

.788 July 17 The Condylarthra. *Amer. Nat.* Vol. XVIII, 1884, pp. 790-805; 892-906, Pls. XXVIII-XXX and figs. 1-28.

Affinities, classification, description of principal forms with illustrations. The article appeared in the August number (published July 17) and the September number (published August 15) successively.

.789 July 17 [An International Scientific Association.] *Amer. Nat.* Vol. XVIII, 1884, pp. 805, 806.

Editorial.

.790 July 17 The Duke of Argyll's Unity of Nature. *Amer. Nat.* Vol. XVIII, 1884, pp. 807, 808.

Review of: The Unity of Nature, by the Duke of Argyll. Unsigned. Cited by Frazer.

.791 July 17 The *Choristodera*. *Amer. Nat.* Vol. XVIII, 1884, pp. 815-817.

Critique of: Etude sur les charactéres géneriques du Simædosaure reptile nouveau de la faune Cernaysiene etc. par Dr. Lemoine, 1884. Probably = *Champsosaurus;* position of this group of fossil reptiles.

.792 July 17 The Genus *Pleuracanthus*. *Amer. Nat.* Vol. XVIII, 1884, p. 818, Pl. XXIII.

Figures of specimens from Texas Permian. See 771 for first note.

.793 Aug. 15 Zoological Nomenclature. *Amer. Nat.* Vol. XVIII, 1884, pp. 906-908.

Unsigned editorial. Given under Cope in index of volume.

.794 Aug. 15 Scientific Illustrations. *Amer. Nat.* Vol. XVIII, 1884, p. 908.

Unsigned editorial. Given under Cope in index of volume.

.795 Aug. 24 (The Age of some Formations in the Banks of the Rio Grande). *Proc. Amer. Philos. Soc.* Vol. XXI, 1884, p. 615.

.796 Sept. 15 Observations on the Phylogeny of the Artiodactyla derived from American Fossils. *Amer. Nat.* Vol. XVIII, 1884, pp. 1034-1036.

An advance abstract of 807. It is composed of the paragraphs from the bottom of p. 25 to end of that paper, com-

prising the author's views of this date in regard to the phylogeny of the families.

.797 On Catagenesis. *Amer. Nat.* Vol. XVIII, 1884, pp. 970-984.
Sept. *Proc. A. A. A. S.* XXXIII Meeting 1884, pp. 455-470. Abstract,
15 "Catagenesis; or, Creation by Retrograde Metamorphosis of Energy", *Science* Vol. IV, No. 84, Sept. 12, 1884, pp. 240-243.

Corollary to the doctrines of archæsthetism, etc., discussed in a previous number of the Amer. Nat. The abstract in Science appeared three days previous to the original in the Amer. Nat. The Proc. A. A. A. S. were not published until 1885.

.798 Scientific Contracts. *Amer. Nat.* Vol. XVIII, 1884, p.
Sept. 1013.
15 Unsigned editorial. Under Cope in index of volume.

.799 Phylogeny of the artiodactyle *Mammalia.* *Science* Vol. IV,
Oct. No. 87, Oct. 3, 1884, p. 339.
3 An abstract of 807. See also 796 and note.

.800 On the Saurians of the Permian Epoch. *Science* Vol. IV,
Oct. No. 87, Oct. 3, 1884, p. 340.
3 Abstract of paper in Proc. A. A. A. S.

.801 The Amblypoda. *Amer. Nat.* Vol. XVIII, 1884, pp. 1110-
Oct. 1121; 1192-1202; Vol. XIX, 1885, pp. 40-55, Pl. I; figs. 1-35.
20 Ordinal characters, classification, affinities of other ungulate orders; descriptions of principal known types with illustrations. The pages appeared successively in the November number (published Oct. 20), the December number (published Nov. 19) and the January number of 1885 (published Dec. 30, 1884).

.802 Note on Acceleration in Deer Antlers. *Amer. Nat.* Vol.
Oct. XVIII, 1884, p. 1160.
20 See also 785.

.803 The American Association for the Advancement of Science.
Oct. *Amer. Nat.* Vol. XVIII, 1884, pp. 1121, 1122.
20 Unsigned editorial. Under Cope in the index of volume.

.804 Catalogue of Aquatic Mammals of the United States by F.
Oct. W. True. *Amer. Nat.* Vol. XVIII, 1884, pp. 1123, 1124.
20 Review with criticism.

.805 The Origin of the Mammalia. *Amer. Nat.* Vol. XVIII,
Oct. 1884, pp. 1136, 1137.
20 Derived from primitive reptilia, the Permian Pelycosauria

approximately represent the ancestral type. Abstract of 819 and 808.

.806 Oct. 21 The Extinct Mammalia of the Valley of Mexico. *Proc. Amer. Philos. Soc.* Vol. XXII, 1884, pp. 1-21. *Pal. Bull.* No. 39, pp. 1-21. Reprinted in Spanish "Los mamiferos dal valle de Mexico ya extinguidos." *Anales, Museo Nacional, Mexico,* T.III, 10*a*, pp. 335-344, 1886.

Based upon study of collections in National and School of Mines Museums of Mexico. Revision of the species of Mastodon, dividing into 3 genera, *Dibelodon,* gen. nov. type *M. shepardi,* Leidy, *Tetrabelodon* gen. nov. type *M. angustidens* Cuv. upon characters of incisors. *Equus,* key to species and descriptions of two new forms; Camelidæ, key to later genera, *Eschatius* gen. nov.

.807 Oct. 21 On the Structure of the Feet in the Extinct Artiodactyla of North America. *Proc. Amer. Philos. Soc.* Vol. XXII, 1884, pp. 21-27. *Pal. Bull.* No. 39, pp. 21-27. *Proc. A. A. A. S.* XXXIII Meeting, 1884, pp. 482-489.

Concise account of principal features of structure of feet in American Tertiary genera; discussion of affinities and evolution; phylogeny of families. For abstract see 796 and 799.

.808 Oct. 21 Fifth Contribution to the Knowledge of the Fauna of the Permian Formation of Texas and the Indian Territory. *Proc. Amer. Philos. Soc.* Vol. XXII, 1884, pp. 28-47, Pl. I. *Pal. Bull.* No. 39, pp. 28-47, Pl. I.

Description of specimens of *Clepsydrops, Cricotus* and *Edaphosaurus;* posterior foot structure in Pelycosauria shows marked affinities to mammalia, especially monotremes; columella auris and quadrate in *Clepsydrops leptocephalus* (postea *Diopeus* Cope = *Theropleura* auct. Case) constructed on pattern distinctly approaching mammalia; articulation of ribs in *Embolophorus* mammaloid; reason for believing that the Mammalia are descendants of the Pelycosauria.

.809 Nov. 19 The Press and Science. *Amer. Nat.* Vol. XVIII, 1884, pp. 1231-1233.

Unsigned editorial. Under Cope in index of volume.

.810 Nov. 19 Original Research in Philadelphia. *Amer. Nat.* Vol. XVIII, 1884, p. 1234.

Unsigned editorial. Under Cope in index of volume.

.811 Nov. 19 The Structure of the *columella auris* in *Clepsydrops leptocephalus.* *Amer. Nat.* Vol. XVIII, 1884, pp. 1253-1255, Pl. XXXVII.

Interpretation of the structure in this Permian reptile bear-

ing upon problem of origin of the mammalian ear ossicles. Abstract of 820. See 808.

.812 Note on the Phylogeny of the Vertebrata. *Amer. Nat.* Vol.
Nov. XVIII, 1884, pp. 1255-1257.
19 Diagram of phyletic relations of the classes of vertebrates. Brief discussion. See also 807.

.813 The psychical Relation of Man to Animals. *Amer. Nat.*
Nov. Vol. XVIII, 1884, pp. 1282-1284.
19 Review of: The psychical Relation of Man to Animals, by Prof. Jos. Le Conte, from the Princeton Review.

.814 (Evolution and the Church.) *Amer. Nat.* Vol. XIX, 1885,
Dec. pp. 55-56.
30 Unsigned editorial. Cited by Frazer.

.815 (Vagaries of Nomenclatures.) *Amer. Nat.* Vol. XIX, 1885,
Dec. pp. 56, 57.
30 Unsigned editorial. Cited by Frazer.

.816 *Rodentia* of the European Tertiaries. *Amer. Nat.* Vol. XIX,
Dec. 1885, p. 67.
30 Review of: Die Nager des europàischen Tertiars nebst Betrachtungen, u. d Organization u. gesch. Entwicklung der Nager überhaupt, von M. Schlosser. Palæontographica, 1884. Unsigned. Cited by Frazer.

.817 Marsh on the Jurassic Dinosauria, Part VIII. *Amer. Nat.*
Dec. Vol. XIX, 1885, pp. 67, 68.
30 Review of: The Principal Characters of the American Jurassic Dinosaurs, Part VIII, Order Theropoda. On the United Metatarsal Bones of *Ceratosaurus*. Amer. Journ. Sci., 1884.

.818 Clevenger on the Evolution of Mind and Body of Man and
Dec. Animals. *Amer. Nat.* Vol. XIX, 1885, pp. 99-101.
30 Review of: Comparative Physiology and Psychology, by S. V. Clevenger.

1885.819 The Relations between the Theromorphous Reptiles and the Monotreme Mammalia. *Proc. A. A. A. S.*, XXXIII Meeting, 1884, pp. 471-482, one plate.
For abstract see 805. See also 808.

.820 The Structure of the *columella auris* in the Pelycosauria. *Mem. Nat. Acad. Sci.* Vol. III, Pt. 1, 1884, pp. 91-95, one plate.
For abstract see 808 and 811.

821 The Occurrence of Man in the Upper Miocene of Nebraska. *Proc. A. A. A. S.*, XXXIII Meeting, 1884, p. 593.
Abstract only. Tooth and associated specimens figured 1395, Pl. CXIXc.

.822 Batrachia. *Standard Natural History* (Edited by J. S. Kingsley) Vol. III, 1885, pp. 303-344.

.823 Genealogy of the Vertebrates as Learned from Palæontology. *Trans. Vassar Brothers' Institute* Vol. III, pp. 60-80.
See also 824, which is nearly the same paper.

.824 Jan. 19 On the Evolution of the Vertebrata, Progressive and Retrogressive. *Amer. Nat.* Vol. XIX, 1885, pp. 140-148; 234-247; 341-353.
Degeneracy and adaptive specialization; embryological and palaeontological evidence; general relations of the vertebrate classes; broader features in evolution of vertebrate anatomy; the Urochorda; evolution of the Fishes and relationships of the orders; Batrachia, key to the orders, phyletic relations; Reptilia, key to orders, phyletic relations, degenerative features in their evolution; birds: key to orders of mammals, phyletic relations, evolution of feet, vertebræ, dentition, brain; instances of degeneracy; progressive evolution prevalent in higher and more recent groups, retrogressive in earlier and lower forms. The paper appeared successively in the February number (published Jan. 19), the March number (published Feb. 24), and the April number (published March 21).

.825 Jan. 19 [The Report of the Museum of Comparative Zoology.] *Amer. Nat.* Vol. XIX, 1885, pp. 148, 149.
Unsigned editorial. Cited by Frazer.

.826 Jan. 19 [Professor Horace Jayne and the School of Biology.] *Amer. Nat.* Vol. XIX, 1885, pp. 149, 150.
Unsigned editorial. Cited by Frazer.

.827 Jan. 19 [The Origin of Speech.] *Amer. Nat.* Vol. XIX, 1885, pp. 150, 151.
Unsigned editorial. Cited by Frazer.

.828 Jan. 19 The White River Beds of Swift Current River, Northwest Territory. *Amer. Nat.* Vol. XIX, 1885, p. 163.
List of species: *Hemipsalodon grandis* gen. et spec. nov. described. Abstract of 881.

.829 Feb. 24 [The National Museum at Washington.] *Amer. Nat.* Vol. XIX, 1885, pp. 276, 277.
Editorial.

.830 Feb. 24 [The Geological Survey of Canada.] *Amer. Nat.* Vol. XIX, 1885, pp. 277, 278.
Unsigned editorial. Cited by Frazer.

.831 Feb. 24 The Position of *Pterichthys* in the System. *Amer. Nat.* Vol. XIX, 1885, pp. 289-291, figs. 1, 2.
Comparison of *Pterichthys* with modern Tunicates.

.832 March 6 Twelfth Contribution to the Herpetology of Tropical America. *Proc. Amer. Philos. Soc.* Vol. XXII, 1884, pp. 167-194, one plate.
With synopses of the Mexican and Central American species of the genera: *Eumeces, Eutænia, Coluber, Phyllodactylus* and of the genera of the Amphisbaenidae, including the new genus *Aporarchus* from Rio Grande do Sul, Brazil.

.833 March 6 The Oldest Tertiary Mammalia. *Amer. Nat.* Vol. XIX, 1885, pp. 385-387.
Lower Puerco (Polymastodon zone as now known), list of fossil mammals, descriptions of *P. latimolis* n. sp., *Laxolophus adapinus* gen. et sp. nov.; *Chriacus hyattianus* n. sp.; *Sarcothraustes coryphaeus* n. sp.

.834 April 20 The Lemuroidea and the Insectivora of the Eocene Period of North America. *Amer. Nat.* Vol. XIX, 1885, pp. 457-471, figs. 1-18.
Osteological distinctions between the orders Lemuroidea and Insectivora; relations of the Condylarthra; families and genera Arctocyonidae (including *Achaenodon*).

.835 April 20 [The Dimensions of Matter.] *Amer. Nat.* Vol. XIX, 1885, p. 482.
Criticism of argument for four-dimensional space. Unsigned editorial. Under Cope in index of volume.

.836 April 20 [The Bestiarians.] *Amer. Nat.* Vol. XIX, 1885, p. 483.
Unsigned editorial. Cited by Frazer.

.837 April 20 The Mammalian Genus *Hemiganus*. *Amer. Nat.* Vol. XIX, 1885, pp. 493, 494.
Hemiganus otariidens sp. nov.

.838 April 20 Marsupials from the Lower Eocene of New Mexico. *Amer. Nat.* Vol. XIX, 1885, pp. 493, 494.
Neoplagiaulax americanus n. sp., *Ptilodus, Polymastodon attenuatus* n. sp. from Puerco formation.

.839 April 20 The Loup Fork Miocene in Mexico. *Amer. Nat.* Vol. XIX, 1885, pp. 494, 495.
Note on occurrence and fossil mammals.

.840 May 1 Phylogeny of the Placental Mammalia. *Science* Vol. V, No. 117, May 1, 1885, p. 354.

.841 May 1 Pretertiary Vertebrates of Brazil. *Science* Vol. V, No. 117, May 1, 1885, pp. 354, 355.
Abstract of 860.

.842 May 18 [The National Academy of Sciences.] *Amer. Nat.* Vol. XIX, 1885, pp. 583, 584.
Unsigned editorial. Cited by Frazer.

.843 May 18 The Batrachia of the Permian Beds of Bohemia, and the Labyrinthodont from the Bijori Group (India). *Amer. Nat.* Vol. XIX, 1885, pp. 592-594.
Review of: Fauna der Gaskohle in d. Kalksteinen d. Perm. formation Böhmens, von Dr. Anton Fritsch, Bd. II, Heft 1; and "The Labyrinthodont from the Bijori Group" by R. Lydekker, Mem. Geol. Survey India, Ser. IV, Vol. I.

.844 May 18 The Genera of Dinocerata. *Amer. Nat.* Vol. XIX, 1885, p. 594.
Note based upon Marsh's monograph; five genera admitted, two of them new (*Ditetrodon* and *Tithcopsis*); the number and characters of lower incisors used to differentiate the genera.

.845 June 20 Original Research, its Motives and Opportunities. *Amer. Nat.* Vol. XIX, 1885, pp. 691-693.
Unsigned editorial. Under Cope in index of volume.

.846 June 20 Marsh on the Dinocerata. *Amer. Nat.* Vol. XIX, 1885, pp. 703-705.
Critical review of: Dinocerata, a Memoir of an Extinct Order of Mammals, by O. C. Marsh. Monograph X, U. S. Geol. Survey, 1885.

.847 July A Six-Horned Giant. *The Museum* Vol. I, No. 3, pp. 33-35.
Loxolophodon cornutus.

.848 July 24 A Contribution to the Herpetology of Mexico. *Proc. Amer. Philos. Soc.* Vol. XXII, 1885, pp. 379-404.
The last two pages contain an "Appendix on a Collection from New Providence, Bahama Islands." The collection of the Commission Cientifica. With synopses of the Mexican species of the genera, *Cinosternum, Anolis, Sceloporus;* and a description of a new genus, *Anelytropsis,* of the Anelytropidæ or Typhlophthalmi lizards.

.849 July 24 Second Continuation of Researches among the Batrachia of the Coal Measures of Ohio. *Proc. Amer. Philos. Soc.* Vol. XXII, 1885, pp. 405-408. *Pal. Bull.* No. 40, pp. 405-408.
Cercariomorphus gen. nov.

.850 July 28 Scientific Criticism. *Amer. Nat.* Vol. XIX, 1885, pp. 777, 778.
Unsigned editorial. Under Cope in index of volume.

.851 July 28 The Mammalia of the Oligocene of Buenos Ayres. *Amer. Nat.* Vol. XIX, 1885, pp. 789, 790.
Review of: Nuevos restos de mamiferos fosiles Oligocenos recogidos por el Prof. Pedro Scalabrini y pertenencientes al Museo provincial de la Ciudad del Parana, por F. Ameghino. Bul. 1 Mus. nac. Acad. Sci. di Cordoba, VIII, p. 5.

.852 July 28 Applied Metaphysics of Sex. *Amer. Nat.* Vol. XIX, 1885, pp. 820-823.

.853 Aug. 15 Garman on *Didymodus*. *Amer. Nat.* Vol. XIX, 1885, pp. 878, 879.
Review of: Bull. Museum of Comparative Zoology, XII, July, 1885.

.854 Sept. Origin of Man and Other Vertebrates. *Pop. Sci. Monthly* Vol. XXVII, 1885, pp. 605-614, figs. 1-3.

.855 Sept. 11 On the Brain and Auditory Organs of a Permian Theromorph Saurian. *Science* Vol. VI, No. 136, Sept. 11, 1885, p. 224.
Abstract of paper read before the A. A. A. S., 1886. See 883.

.856 Sept. 22 [The United States Coast Survey.] *Amer. Nat.* Vol. XIX, 1885, p. 974.
Unsigned editorial. Cited by Frazer.

.857 Sept. 22 The Relations of the Puerco and Laramie Deposits. *Amer. Nat.* Vol. XIX, 1885, pp. 985, 986.
Puerco formation overlies Laramie with characteristic dinosaurs. Both, however, may be associated in the Post-cretaceous series. *Crocodilus stavilianus* described from Laramie of New Mexico.

.858 Sept. 22 The large Iguanas of the Greater Antilles. *Amer. Nat.* Vol. XIX, 1885, pp. 1005, 1006.
Notes on distribution; key to species of *Cyclura*.

.859 Sept. 22 M. Paul Albrecht's Identifications. *Amer. Nat.* Vol. XIX, 1885, pp. 1006-1009.
Homologies of skull bones in mammals and lower vertebrates. Critical review. Unsigned. Under Cope in index of volume.

860 Sept. 26 A Contribution to the Vertebrate Palaeontology of Brazil. *Proc. Amer. Philos. Soc.* Vol. XXIII, 1885, pp. 1-21, one plate. *Pal. Bull.* No. 40, pp. 1-21, one plate.

For abstract see 841. Description of skeleton of *Stereosternum* "carboniferous" (Permian) and also *Hyposaurus.* New species of fishes of genera *Apocopodon, Enchodus, Diplomystus, Chiromystus* and *Pycnodus* described.

.861 Oct. The Energy of Life Evolution, and how it has acted. *Pop. Sci. Monthly* Vol. XXVII, 1885, pp. 789-800, figs. 1-9.

.862 Oct. 23 The Present Condition of the Yellowstone National Park. *Amer. Nat.* Vol. XIX, 1885, pp. 1037-1040.

.863 Oct. 23 [The Destruction of Animals.] *Amer. Nat.* Vol. XIX, 1885, pp. 1077, 1078.

Unsigned editorial. Cited by Frazer.

.864 Oct. 23 [The Comision cientifica of Mexico.] *Amer. Nat.* Vol. XIX, 1885, p. 1079.

Unsigned editorial. Cited by Frazer.

.865 Oct. 23 Eocene Paddle-fish and Gonorhynchidæ. *Amer. Nat.* Vol. XIX, 1885, pp. 1090, 1091.

Green River Eocene fish fauna: *Crossopholis* a relative of *Polyodon; Notogoneus osculus* gen. et sp. nov. of Gonorhynchidæ.

.866 Oct. 26 Catalogue of the Species of Batrachians and Reptiles contained in a Collection made at Pebas, Upper Amazon, by John Hauxwell. *Proc. Amer. Philos. Soc.* Vol. XXIII, 1885, pp. 94-103.

With a new genus, *Mionyx,* and a synopsis of the Ecplopodine division of the Teidæ.

.867 Nov. Mr. Lydekker on *Esthonyx. Geol. Mag.* n. s. Decade 3, Vol. II, 1885, pp. 526, 527.

.868 Nov. The Batrachia of the Permian Beds of Bohemia. *Geol. Mag.* n. s. Decade 3, Vol. II, 1885, p. 527.

.869 Nov. 25 [The Political Scientists.] *Amer. Nat.* Vol. XIX, 1885, pp. 1186, 1187.

Unsigned editorial. Cited by Frazer.

.870 Nov. 25 [The Geological Survey of Michigan.] *Amer. Nat.* Vol. XIX, 1885, pp. 1187, 1188.

Unsigned editorial. Cited by Frazer.

.871 Nov. 25 Jordan's Catalogue of Fishes of North America. *Amer. Nat.* Vol. XIX, 1885, pp. 1199, 1200.

Review of: Catalogue of the Fishes known to inhabit the

Waters of North America north of the Tropic of Cancer, by D. S. Jordan (extracted from Annual Report, U. S. Commissioner of Fish and Fisheries, for 1884).

.872 Nov. 25 Polemics in Palæontology. *Amer. Nat.* Vol. XIX, 1885, pp. 1207, 1208.
Unsigned. Cited by Hay.

.873 Nov. 25 The Ankle and Skin of the Dinosaur, *Diclonius mirabilis*. *Amer. Nat.* Vol. XIX, 1885, p. 1208, figs. 1-3, of Pl. XXXVII.
Note on characters seen in skeleton found by Wortman and Hill in South Dakota, now mounted in the American Museum (Cope Collection).

.874 Nov. 25 Pliocene Horses of Southwestern Texas. *Amer. Nat.* Vol. XIX, 1885, pp. 1208, 1209, figs. 4-6 of Pl. XXXVII.
Five species noted; figure of *E. ? crenideus* upper molar, also of upper molars of *Hippotherium peninsulatum* n. sp. and *Protohippus castilli* n. sp. from Mexican Tertiary. Abstract of 877.

.875 Nov. 25 The Retrograde Metamorphosis of Siren. *Amer. Nat.* Vol. XIX, 1885, pp. 1226, 1227.

.876 Dec. Palæontological Nomenclature. *Geol. Mag.* n. s. Decade 3, Vol. II, 1885, pp. 572-575.

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Geological notes: *Hippotherium peninsulatum* and *Protohippus castilli* further described. For abstract see 874.

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Unsigned editorial. Cited by Frazer.

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See 828 for abstract.

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Species of *Crassopholis, Notogeneus and Priscacara (H. hyssacanthus* N. Sp) described.

883 Jan. 21 On the Structure of the Brain and Auditory Apparatus of a Theromorphous Reptile of the Permian Epoch. *Proc. Amer. Philos. Soc.* Vol. XXIII, 1885, pp. 234-238, one plate. *Proc. A. A. A S.*, XXXIV Meeting, 1885, p. 336-341.
Study of a brain-cast and sectional skull of *Diadectes.* For abstract see 855.

884 Jan. 23 [The Academy of Original Research.] *Amer. Nat.* Vol. XX, 1886, pp. 140-142.
Editorial. Plan for such an institution.

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Description and figures of *Diclonius* and *Monoclonius.* (This element in *Monoclonius* subsequently identified as the "frill" at the back of the neck.)

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Tetheopsis founded upon an artefact; basicranium described by Cope in "Tertiary Vertebrata" as *Uintatherium lacustre* is a *Palaeosyops.*

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Traces of a true intercentrum are present in this reptile.

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.890 Feb. 25 (The Bestiarians.) *Amer. Nat.* Vol. XX, 1886, p. 254.
Unsigned editorial. Cited by Frazer.

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Notice of J. A. Allen's memoir on *Pachycyon robustus, Mem. Mus. Comp. Zool.* Vol. X, No. 2. Unsigned. Cited by Hay.

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Charina, Lichanura and *Loxocemus.* Systematic position.

.893 Feb. 25 An Extraordinary Human Dentition. *Amer. Nat.* Vol. XX, 1886, p. 297.

.894 March *Edestus* and *Pelecopterus,* etc. *Geol. Mag.* n. s. Decade 3. Vol. III, 1886, p. 141.
Pelecopterus not identical with *Ptychodus.*

.895 March 23 The Vertebrate Fauna of the *Ticholeptus* Beds. *Amer. Nat.* Vol. XX, 1886, pp. 367-369.
Mascall and Deep River faunas compared. *Anchitherium ultimum* and *Merycochoerus obliquidens* described from Cottonwood Creek, Oregon (Mascall formation). Abstract of 896.

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Fuller description and discussion than in abstract; *Hippotherium rectidens* n. sp. from Tehuichila. For abstract see 895.

.897 April 20 On the Intercentrum of the Terrestrial Vertebrata. *Trans. Amer. Philos. Soc.* n. s. Vol. XVI, 1886, pp. 243-253, Pl. I and figs. 1-6. Separates April 20, 1886.

.898 April 24 [The Relations of the National Academy of Sciences to the Government.] *Amer. Nat.* Vol. XX, 1886, pp. 443, 444.
Editorial.

.899 April 24 The Plagiaulacidæ of the Puerco Epoch. *Amer. Nat.* Vol. XX, 1886, p. 451.
Neoplagiaulax molestus sp. nov.

.900 April 24 Meynert's Psychiatry. *Amer. Nat.* Vol. XX, 1886, pp. 474-479.
Review of: Psychiatry, a clinical Treatise on Diseases of the Fore-Brain, by Theodor Meynert. Translated by B. Sachs.

.901 May Note on *Phenacodus.* *Geol. Mag.* n. s. Decade III, Vol. III, 1886, p. 239.

.902 May Note on *Erisichthe.* *Geol. Mag.* n. s. Decade III, Vol. III, 1886, p. 239.
Erisichthe not synonymous with *Protosphyræna.*

.903 June 1 [The Missing Link.] *Amer. Nat.* Vol. XX, 1886, pp. 534-536.
Unsigned editorial. Cited by Frazer.

.904 June 1 [The Congressional Investigation of the United States Geological Survey.] *Amer. Nat.* Vol. XX, 1886, p. 536.
Unsigned editorial.

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Description of *Naosaurus claviger*, key to species of *Naosaurus*.

.906 July The Phylogeny of the Camelidæ. *Amer. Nat.* Vol. XX, 1886, pp. 611-624, figs. 1-14.
Characteristics of Camelidae; key to genera; description of ancestral series, carried back to "*Pantolestes*" *brachystomus* (i. e., *Diacodexis*).

.907 July [A Government Department of Science and Public Instruction.] *Amer. Nat.* Vol. XX, 1886, pp. 624, 625.
Unsigned editorial. Cited by Frazer.

.908 July Embryology of Armadillos. *Amer. Nat.* Vol. XX, 1886, pp. 667, 668.

.909 Aug. [Theology of Evolution.] *Amer. Nat.* Vol. XX, 1886, pp. 708, 709.
Unsigned editorial. Cited by Frazer.

.910 Aug. [Illustration in United States Geological Survey Work.] *Amer. Nat.* Vol. XX, 1886, pp. 709, 710.
Unsigned editorial. Cited by Frazer.

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Critical review of: Beiträge zur Kenntniss der Stammesgeschichte der Hufthiere und Versuch einer Systematik der Paar—und Unpaarhufer, von Max Schlosser. Morph. Jahrbuch. XII, s. 575-580. Taxonomic methods and systematic criteria; origin of the milk dentition.

.912 Aug. The most Southern Salmon. *Amer. Nat.* Vol. XX, 1886, p. 735.
Salmo purpuratus from Sierra Madre, Mexico.

.913 Aug. The Habits of *Eublepharis variegatus* Baird. *Amer. Nat.* Vol. XX, 1886, pp. 735, 736.

.914 Aug. The Copperhead and other Snakes. *Amer. Nat.* Vol. XX, 1886, pp. 744, 745.
Fear of hognose and water snake for copperhead.

.915 Aug. 7 On the Structure and Affinities of the Amphiumidæ. *Proc. Amer. Philos. Soc.* Vol. XXIII, 1886, pp. 442-445, Pls. VI, VII.

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.917 Oct. 18 [The Method of Teaching Natural History.] *Amer. Nat.* Vol. XX, 1886, pp. 868, 869.
Unsigned editorial. Cited by Frazer.

.918 Oct. 18 [The Recent Charleston Earthquake.] *Amer. Nat.* Vol. XX, 1886, pp. 869, 870.
Unsigned editorial. Cited by Frazer.

.919 Oct. 18 [Concerning Appropriations for the United States Geological Survey.] *Amer. Nat.* Vol. XX, 1886, p. 870.
Editorial.

.920 Oct. 23 Systematic Catalogue of the Species of Vertebrata found in the Beds of the Permian Epoch in North America with Notes and Descriptions. *Trans. Amer. Philos. Soc.* n. s. Vol. XVI, 1886, pp. 285-297, Pls. II, III and one figure. Separates October 23, 1886.

.921 Nov. The Origin of the Fittest. D. Appleton & Co., New York, 8vo., 1886, pp. i-xix; 1-467; Pls. I-XVIII and figs. 1-81.

.922 Nov. 2 Synonymic List of the North American Species of *Bufo* and *Rana*, with Descriptions of some New Species of Batrachia, from Specimens in the National Museum. *Proc. Amer. Philos. Soc.* Vol. XXIII, 1886, pp. 514-526.

.923 Nov. 23 On Lemurine Reversion in Human Dentition. *Amer. Nat.* Vol. XX, 1886, pp. 941-947.
The third or second and third upper molars in man are very commonly tritubercular as in primitive lemuroids instead of quadritubercular as in monkeys and apes. This is especially true of the higher races of man, and is regarded as a reversionary character.

.924 Nov. 23 [Instruction and Investigation.] *Amer. Nat.* Vol. XX, 1886, p. 948.
Unsigned editorial. Cited by Frazer.

.925 Nov. 23 Schlosser on Creodonta and *Phenacodus*. *Amer. Nat.* Vol. XX, 1886, pp. 965-967.
Reply to Ueber das Verhältniss der Cope'schen Creodonta zu den übrigen Fleisch-fressern, von Max Schlosser. *Morph. Jahrbuch,* XII, 1886, p. 287.

.926 Dec. 29 Dollo on Extinct Tortoises. *Amer. Nat.* Vol. XX, 1886, pp. 967, 968.
Review of: Premiére note sur les Cheloniens de Bruxellien de la Belgique, par L. Dollo; Bull. Mus. Roy, de Belgique,

1886, p. 75; and Première note sur les Cheloniens Landemiens de la Belgique; l. c., p. 129

.927 Dec. 29 An Interesting Connecting Genus of Chordata. *Amer. Nat.* Vol. XX, 1886, pp. 1027-1031, fig. 1.

Mycterops ordinatus gen. et sp. nov. intermediate between Ostracoderms and primitive fishes.

.928 Dec. 29 A Giant Armadillo from the Miocene of Kansas. *Amer. Nat.* Vol. XX, 1886, pp. 1044-1046.

Unsigned. Cited by Hay and Frazer. *Caryoderma snovianum.* Subsequently recognized as limb-armor and tee-bones of a giant tortoise.

1887.929 Catalogue of Batrachians and Reptiles of Central America and Mexico. *Bull. U. S. Nat. Museum,* No. 32, 1887, 98 pp.

.930 Jan. The Doctrine of Evolution. *The Agassiz Companion* (Wyandotte, Kansas), Vol. XX, No. 1, Jan., pp. 1-3; No. 2, Feb., p. 14.

.931 Jan. [American Biological Instruction.] *Amer. Nat.* Vol. XXI, 1887, pp. 59-61.

Unsigned editorial. Cited by Frazer.

.932 Jan. The Hyoid Structure in the Amblystomid Salamanders. *Amer. Nat.* Vol. XXI, 1887, pp. 87, 88, figs. 1-3.

.933 Feb. Vertebrate Palæontology. *Amer. Nat.* Vol. XXI, 1887, pp. 164-166.

Statement of circumstances relating to delayed publication of final reports of Hayden Survey on Vertebrate Palaeontology. Unsigned editorial. Under Cope in index of volume.

.934 Feb. The Formations of the Belly River of Canada. *Amer. Nat.* Vol. XXI, 1887, pp. 171, 172.

Comment on Dawson's report on the geological survey.

.935 April The Theology of Evolution. Arnold & Co., Philadelphia, 1887, 37 pp. Synopsis, *Amer. Nat.* Vol. XXI, 1887, pp. 1127-1129.

The exact date not known but first criticised on April 28, 1887.

.936 April Note (on the genus *Dendrobates*). *Amer. Nat.* Vol. XXI, 1887, pp. 310, 311.

.937 April [The Odium antitheologicum.] *Amer. Nat.* Vol. XXI, 1887, pp. 356, 357.

Unsigned editorial. Cited by Frazer.

.938 April The Dinosaurian Genus *Cœlurus*. *Amer. Nat.* Vol. XXI, 1887, pp. 367-369.

Remarks upon its affinities (based upon specimens from

Trias of New Mexico, subsequently removed to *Tanystrophaeus* v. Mey. and later made types of *Coelophysis* Cope).

.939 April Sex in Government. *Amer. Nat.* Vol. XXI, 1187, pp. 399, 400.

.940 April 7 Science and Immortality. *Christian Register*, April 7, 1887.

.941 April 28 Synopsis of the Batrachia and Reptilia obtained by H. H. Smith in the Province of Matto Grosso, Brazil. *Proc. Amer. Philos. Soc.* Vol. XXIV, 1887, pp. 44-50. Abstract, "Brazilian Reptilia," *Amer. Nat.* Vol. XXI, 1887, pp. 388, 389.

See also 942.

.942 April 28 Appendix on a *Leptognathus* from San Paolo. *Proc. Amer. Philos. Soc.* Vol. XXIV, 1887, p. 60.

L. garmani n. sp.

.943 May The Mesozoic and Cænozoic Realms of the Interior of North America. *Amer. Nat.* Vol. XXI, 1887, pp. 445-462.

Read at the International Geological Congress, 1887. Synopsis of classification, distribution of formations and distinctive features of vertebrate faunae. The Laramie group and Puerco are here included in the Mesozoic as Postcretacic system.

.944 May Kedzie's Gravitation, Solar Heat, and Sun Spots. *Amer. Nat.* Vol. XXI, 1887, pp. 464, 465.

Review of: Solar Heat, Gravitation, and Sun Spots, by Prof. J. H. Kedzie.

.945 May American Triassic Rhynchocephalia. *Amer. Nat.* Vol. XXI, 1887, p. 468.

Typothorax from Triassic of New Mexico.

.946 May Some New Tæniodonta of the Puerco. *Amer. Nat.* Vol. XXI, 1887, p. 469.

Additional specimens of *Psittacotherium* described.

.947 May Mr. Hill on the Cretaceous of Texas. *Amer. Nat.* Vol. XXI, 1887, pp. 469, 470.

Review of: The Cross-timbers of Texas, by R. T. Hill. Read before the Washington Philos. Soc.

.948 June [The Michigan Geological Survey.] *Amer. Nat.* Vol. XXI, 1887, p. 551.

Unsigned editorial.

.949 June The Sea-Saurians of the Fox Hills Group. *Amer. Nat.* Vol. XXI, 1887, pp. 563-565.

Describes *Piptomerus* gen. nov. with three species, and a new

species of Orophosaurus from fragmentary material obtained in New Mexico.

.950 June — The Marsupial Genus *Chirox*. *Amer. Nat.* Vol. XXI, 1887, pp. 566, 567, figs. 1, 2.
Description of palate with upper dentition.

.951 June — Evolution and Idealism. *Amer. Nat.* Vol. XXI, 1887, pp. 594, 595.

.952 July — [The International Congress of Geologists.] *Amer. Nat.* Vol. XXI, 1887, pp. 643-645.
Unsigned editorial. Cited by Frazer.

.953 July — Pavlow on the Ancestry of Ungulates. *Amer. Nat.* Vol. XXI, 1887, pp. 656-658.
Critical review of: Études sur l'histoire paléontologique des Ongulés en Amérique et en Europe. I—Groupe primitive de l'Eocène inférieur.

.954 July — [Note on the Brain-case of *Belodon buceros*.] *Amer. Nat.* Vol. XXI, 1887, pp. 659, 660.
Verbal communication to the Amer. Philos. Soc.

.955 July 2 — On a New Species of *Tropidonotus* found in Washington. *Proc. U. S. National Museum* Vol. X, 1887, p. 146,
T. bisectus.

.956 July 7 — Montgomery on the Theology of Evolution. *Open Court* Vol. I, No. 11, July 7, 1887, pp. 285-288; Vol. I, No. 13, Aug. 4, 1887 pp. 358-361.
Reprinted as a pamphlet under the title, "A Review of the Theology of Evolution; A Reply to Dr. Montgomery."

.957 July 8 — A Contribution to the History of the Vertebrata of the Trias of North America. *Proc. Amer. Philos. Soc.* Vol. XXIV, 1887, pp. 209-228, Pls. I, II.
Based chiefly upon New Mexican collections. Additional notes on *Eupelor, Typothorax, Belodon, Tanystrophaeus* (olim *Coelurus,* postea *Coelophysis*); *Episcoposaurus* gen. nov.

.958 Sept. — The American Association at New York. *Amer. Nat.* Vol. XXI, 1887, pp. 833-835.
Unsigned editorial. Under Cope in index of volume.

.959 Sept. — The American Committee of the International Congress of Geologists. *Amer. Nat.* Vol. XXI, 1887, pp. 835, 836.
Unsigned editorial. Under Cope in index of volume.

.960 Sept. — The Death of Spencer F. Baird. *Amer. Nat.* Vol. XXI, 1887, pp. 836, 837.
Unsigned editorial. Under Cope in index of volume.

.961 Sept. What is the Object of Life? *The Forum* Vol. IV, pp. 49-57.

.962 Sept. 15 Descriptions of New Species of Mexican Reptiles. *Proc. U. S. Nat. Museum* Vol. IX, pp. 184, 188, 189, 190, 196.

These pages are in an article, "Catalogue of Animals collected by the Geographical and Exploring Commission of the Republic of Mexico," by M. Fernando Ferrari-Perez.

.963 Oct. Scott and Osborn on White River Mammalia. *Amer. Nat.* Vol. XXI, 1887, pp. 924-926.

Review of: Preliminary Account of the Fossil Mammals from the White River Formation contained in the Museum of Comparative Zoology, Cambridge, Mass., by W. B. Scott and H. F. Osborn. *Bull. Mus. Comp. Zoo.* Vol. XIII, No. 5.

.964 Oct. Marsh on New Fossil Mammalia. *Amer. Nat.* Vol. XXI, 1887, pp. 926, 927.

Review of: Notice of New Fossil Mammals by O. C. Marsh. *Amer. Journ. Sci.*, Oct., 1887, p. 323.

.965 Oct. Scott on Creodonta. *Amer. Nat.* Vol. XXI, 1887, p. 927.

Review of: On some New and Little-known Creodonta, by W. B. Scott, *Journ. Acad. Nat. Sci. Phila.*, Aug. 10, 1887.

.966 Oct. Scientific Theism. *Amer. Nat.* Vol. XXI, 1887, pp. 948-951.

Review of: Scientific Theism, by Francis Ellingwood Abbot, 2d edition.

.967 Oct. 23 The Relation of Mind to Matter. *Open Court* Vol. I, No. 19, Oct. 27, 1887, pp. 527-530.

.968 Nov. The Perissodactyla. *Amer. Nat.* Vol. XXI, 1887, pp. 985-1007; 1060-1076; Pls. XXVIII-XXXIV; figs. 1-44.

The paper appeared successively in the November and December numbers. Structure and origin of the Perissodactyl foot; characters and evolution of the cheek teeth; synopsis of families and review of principal genera in each, with illustrations of important specimens, generic keys, and phylogenies.

.969 Nov. The Relation of Mind to Matter. *Amer. Nat.* Vol. XXI, 1887, pp. 1007, 1008.

Unsigned editorial. Under Cope in index of volume.

.970 Nov. Synopsis of the Flora of the Laramie Group. *Amer. Nat.* Vol. XXI, 1887, pp. 1011, 1012.

Review of: Synopsis of the Flora of the Laramie Group, by Lester F. Ward, Ann. Report, U. S. Geol. Survey of the Territories, 1886, p. 400.

.971 Nov. Zittel's Manual of Palæontology. *Amer. Nat.* Vol. XXI, 1887, pp. 1014-1019.
Review of: Handbuch der Palæontologie, von K. A. von Zittel, Abtheilungen I, Palaezoologie, Lief. I, Pisces, etc., 1887. Chiefly a synopsis of Cope's own views on the classification of the fishes, etc.

.972 Nov. A Saber-tooth Tiger from the Loup Fork Beds. *Amer. Nat.* Vol. XXI, 1887, pp. 1019, 1020.
Machaerodus catocopis from Republican River beds in Kansas.

.973 Nov. 3 List of the Batrachia and Reptilia of the Bahama Islands. *Proc. U. S. Nat. Museum* Vol. X, 1887, pp. 436-439.

.974 Nov. 29 The Classification and Phylogeny of the Artiodactyla. *Proc. Amer. Philos. Soc.* Vol. XXIV, 1887, pp. 377-400.
Key to families; phylogeny of families; synopsis of principal genera in each family with key and phylogeny. See also 1031.

.975 Dec. Thomas on Mammalian Dentition. *Amer. Nat.* Vol. XXI, 1887, pp. 1134, 1135.
Review of: On the Homologies and Succession of the Teeth in the Dasyuridæ, with an attempt to trace the History of the Evolution of Mammalian Teeth in General, by Oldfield Thomas, Philos. Trans. Roy. Soc., 1887, p. 443.

.976 Dec. The Carboniferous Genus *Stereosternum. Amer. Nat.* Vol. XXI, 1887, p. 1109.
Notes on a nearly entire skeleton from Sao Paolo, Brazil.

.977 Dec. The Pug-dog and the Chihuahua Dog. *Amer. Nat.* Vol. XXI, 1887, pp. 1125, 1126.
Generically distinct from *Canis* on basis of number of teeth; genera *Synagodus* and *Dysodus*.
Unsigned. Cited by Frazer.

.978 Dec. The Death of Ferdinand V. Hayden. *Amer. Nat.* Vol. XXI, 1887, pp. 1134, 1135.
Unsigned. Cited by Frazer.

.979 Dec. Lydekker, Boulenger and Dollo on Fossil Tortoises. *Geol. Mag.* n. s. Decade 3, Vol. IV, 1887, pp. 572, 573.

1888.980 Jan. 5 Evolution and Idealism. *Open Court* Vol. I, No. 23, Jan. 5, 1888, pp. 655-657. Reprint, *Amer. Nat.* Vol. XXII, 1888, pp. 81-84.

.981 Jan. 10 The Mechanical Origin of the Sectorial Teeth of the Carnivora. *Proc. A. A. A. S.* XXXVI Meeting, 1887, pp. 254-257. Separates dated Jan. 10, 1888.

The Rodentia are derived from the Tillodontia, certain Taeniodonta being largely intermediate in structure of teeth. The Taeniodonta may also (footnote) be structurally ancestral to the Edentata. Evolution of the characteristic palinal jaw movement in rodents causing the evolution of their characteristic dentition (through kinetogenesis).

.982 Feb. 3 The Mechanical Origin of the Dentition of the Rodentia. *Amer. Nat.* Vol. XXII, 1888, pp. 3-11, figs. 1-9.

Derivation of the order from Tillodont-Taeniodont group. Character of jaw movements in rodents and mechanical effect upon the tooth structures. Parallelism in Multituberculata.

.983 Feb. 3 Note on the Marsupialia Multituberculata. *Amer. Nat.* Vol. XXII, 1888, pp. 12, 13.

Structure of their teeth indicates palinal movement of jaws as in Rodentia.

.984 Feb. 3 (On Local Names.) *Amer. Nat.* Vol. XXII, 1888, pp. 44, 45.

Unsigned editorial. Cited by Frazer.

.985 March 1 Note (on Dr. Montgomery's argument.) *Open Court* Vol. II, No. 27, March 1, 1888, p. 777.

.986 April 2 The Vertebrate Fauna of the Puerco Epoch. *Amer. Nat.* Vol. XXII, 1888, pp. 161-163.

Abstract of 1009. The Puerco a distinct epoch: characters of the mammalian fauna. All plantigrade pentadactyl bunodonts and nearly all have tritubercular molars. Multituberculata present. Perissodactyls and Rodents absent. Fauna ancestral to Eocene and later faunae.

.987 April 2 Schlosser on the Caenozoic Marsupials and Unguiculata. *Amer. Nat.* Vol. XXII, 1888, pp. 163, 164.

Critical review of: Die Affen, Lemuren, Cheiropteren, Insectivoren, Marsupialier, Creodonten u. Carnivoren d. europäischen Tertiärs, von Max Schlosser. Teil I, 1887.

.988 April 2 Lydekker's Catalogue of Fossil Mammalia in the British Museum, Part V. *Amer. Nat.* Vol. XXII, 1888, pp. 164, 165.

Critical review of: Catalogue of the Fossil Mammalia in the British Museum, Part V—containing the Tillodontia, Sirenia, Cetacea, Edentata, Marsupialia, Monotremata and Supplement, by Richard Lydekker, 1887.

.989 April 3 On the Dicotylinæ of the John Day Miocene of North America. *Proc. Amer. Philos. Soc.* Vol. XXV, 1888, pp. 62-79.

.990 April 4 On the Mechanical Origin of the Dentition in the Amblypoda. *Proc. Amer. Philos. Soc.* Vol. XXV, 1888, pp. 80-88, figs. 1-6.

.991 April 21 Seebohm on the *Charadriidæ*. *Amer. Nat.* Vol. XXII, 1888, pp. 236, 237.
Review of: The Geographical Distribution of the *Charadriidæ*, by Henry Seebohm, 1887.

.992 April 21 The Multituberculata Monotremes. *Amer. Nat.* Vol. XXII, 1888, p. 259.
Vestigial teeth of *Ornithorhynchus* indicate that the Multituberculates belong to this group instead of the Marsupials.

.993 April 21 The Cope-Montgomery Discussion. *Amer. Nat.* Vol. XXII, 1888, pp. 264-267.
Discussion of "The Theism of Evolution." Synopsis of Cope's views presented in "The Open Court" during 1887.

.994 April 27 Vertebrate Fauna of the Puerco Series. *Science* Vol. XI, No. 273, April 27, 1888, p. 198.
Abstract of 1009.

.995 May 25 Glyptodon from Texas. *Amer. Nat.* Vol. XXII, 1888, pp. 345, 346.
G. petaliferus sp. nov. based on a single plate of the carapace, from Nueces Co., Texas.

.996 May 31 What Mind is. *Open Court,* Vol. II, No. 40, May 31, 1888, pp. 991-993.

.997 June 14 The Physical Basis of Mind. *Open Court,* Vol. II, No. 42, June 14, 1888, p. 1034.

.998 June 29 (Privileged Persons in Science.) *Amer. Nat.* Vol. XXII, 1888, pp. 433-435
Unsigned editorial. Cited by Frazer. Illustrations versus descriptions.

.999 June 29 [The Purchase of Intelligence.] *Amer. Nat.* Vol. XXII, 1888, p. 435.
Credit for work of assistants.

.1000 June 29 Baur's Morphogeny of the Carpus and Tarsus of the Vertebrata. *Amer. Nat.* Vol. XXII, 1888, pp. 435-437.
Review of: Beiträge zur Morphogenie des Carpus and Tarsus der Vertebraten, von Dr. G. Baur, Theil I—Batrachia.

.1001 The Phylogeny of the Horses. *Amer. Nat.* Vol. XXII, 1888,
June pp. 448, 449.
29 Critical review of: Études sur l'histoire palæontologique des Ongulés, II—Le Développement des Equidæ, par Marie Pavlow, 1888. Exception taken to Pavlow's exclusion of genus *Hipparion* from ancestry of Equidæ on basis of divergent characters of certain European species.

.1002 The *ossicula auditus* of the Batrachia. *Amer. Nat.* Vol. XXII,
June 1888, pp. 464-467, Pl. VI.
29 Abstract of paper read before the National Academy of Sciences, April 18, 1888. For complete form of paper see 1022.

.1003 On the Tritubercular Molar in Human Dentition. *Journ.*
July *Morph.* Vol II, 1888, pp. 7-26, Pls. II, III and fig.

.1004 On a New Species of *Bufo* from Texas. *Proc. U. S. Nat.*
July *Museum,* Vol XI, 1888, pp. 317, 318.
5 *Bufo aduncus.*

.1005 On the Snakes of Florida. *Proc. U. S. Nat. Museum* Vol.
July XI, 1888, pp. 381-394, Pl. XXXVI, figs. 3, 4.
5 With a key to the genus *Ophibolus.*

.1006 Catalogue of the Batrachia and Reptilia brought by William
July Taylor from San Diego, Texas. *Proc. U. S. Nat. Museum*
5 Vol XI, 1888, pp. 395-398, Pl. XXXVI, fig. 2.
Including a new genus of lizard, *Lysoptychus.*

.1007 On the Eutæniæ of Southeastern Indiana. *Proc. U. S. Nat.*
July *Museum* Vol. XI, 1888, pp. 399-401.
5

.1008 On the Shoulder-girdle and Extremities of *Eryops. Trans.*
July *Amer. Philos. Soc.* n. s. Vol. XVI, 1888, pp. 362-367, one
20 plate. Separates July 20, 1888.
Figures 4 and 4a erroneously numbered 1 and 2 on Plate.

.1009 Synopsis of the Vertebrate Fauna of the Puerco Series.
Aug. *Trans. Amer. Philos. Soc.* n. s. Vol. XVI, 1888, pp. 208-
1 361, Pls. IV, V and figs. 1-12. Separates August 1, 1888.
For abstract see 986 and 994.

.1010 [A National Zoölogical Park at Washington.] *Amer. Nat.*
Aug. Vol. XXII, 1888, pp. 515, 516.
8 Unsigned editorial. Cited by Frazer.

.1011 The Relation of Will to the Conservation of Energy. *Amer.*
Aug. *Nat.* Vol. XXII, 1888, pp. 551-555.
8 Abstract of paper read before the Philosophical Society of Washington under the title, "The Relation of Consciousness to Animal Motion," on May 26, 1888.

.1012 Aug. 30 (Notes on *Cœlosteus ferox* Newberry and *Titanichthys clarkii* Newberry.) *Amer. Nat.* Vol. XXII, 1888, pp 637, 638.

Unsigned. Cited by Hay. Brief description of remains.

.1013 Aug. 30 Topinard on the Latest Steps in the Genealogy of Man. *Amer. Nat.* Vol XXII, 1888, pp. 660-663.

Review of: Les dernières de la génealogie de l'homme. Leçon de Mars 1888, Revue d' Anthropol. May 1888. Gives a subordinal classification of Taxaeopoda (including Hyracoids, Condylarths and Primates) and a phyletic arrangement of the families.

.1014 Sept. 30 Goode's American Fishes. *Amer. Nat.* Vol. XXII, 1888, pp. 714-716. Pl. XIII.

Review of: American Fishes. A Popular Treatise upon the Game and Food Fishes of North America, by G. Brown Goode, 1888.

.1015 Sept. 30 Osborn on the Mesozoic Mammalia. *Amer. Nat.* Vol. XXII, 1888, pp. 723. 724; Pl. XIV.

Review of: The Structure and Classification of the Mesozoic Mammalia, by Prof. H. F. Osborn, *Journ. Acad. Nat. Sci. Phila.*, 1888, pp. 186-265.

.1016 Sept. 30 Lydekker on the Ichthyosauria and Plesiosauria. *Amer. Nat.* Vol. XXII, 1888, pp. 724-726.

.1017 Oct. Mesozoic Realm. *Amer. Geol.* Vol. II, 1888, pp. 261-268.

Abstract, reports, American committee, International Congress of Geologists.

.1018 Oct. Cenozoic Realm. *Amer. Geol.* Vol. II, 1888, pp. 285-299.

Abstract, reports, American committee, International Congress of Geologists.

.1019 Oct. The Relation of the Sexes to Government. *Pop. Sci. Monthly* Vol. XXXIII, 1888, pp. 721-730.

.1020 Oct. 24 (Irrigation of the Arid Region of the United States.) *Amer. Nat.* Vol. XXII, 1888, pp. 821, 822.

Unsigned editorial. Cited by Frazer. Discussion of Powell's proposal for government reservoirs in Rocky Mountain region.

.1021 Oct. 24 Rutimeyer on the Classification of Mammalia, and on American Types recently found in Switzerland. *Amer. Nat.* Vol. XXII, 1888, pp. 831-835.

Review of: Ueber einige Beziehungen zwischen den Saügethierstammen alter u. neuer Welt. Erster Nachtrag zu der Eocenen Fauna der Egerkingen, von L. Rütimeyer, Abhandl,

Schweiz. Palæontol. Gesell. Bd. XV, 1888. Reply to criticisms of Cope's classification of Ungulata by their foot-structure; acknowledges Rütimeyer's priority in elucidating structure of molar teeth.

.1022 On the Relation of the Hyoid and Otic Elements of the
Nov. Skeleton in the Batrachia. *Journ. Morph.* Vol. II, 1888, pp. 297-310, Pls. XXII-XXIV.
For abstract see 1002.

.1023 On a New Species of *Charina* from California. *Proc. U. S.*
Nov. *Nat. Museum* Vol. XI, 1888, p. 88, Pl. XXXVI, fig. 1.
8 *Charina brachyops* from Point Reyes.

.1024 The Marriage Problem. *Open Court* Vol. II, pp. 1307-
Nov. 1310; 1320-1324.
15 The article appeared successively November 15 and 22.

.1025 The Pineal Eye in Extinct Vertebrates. *Amer. Nat.* Vol.
Nov. XXII, 1888, pp. 914-917, Pls. XV-XVIII. Abstract, Proc.
22 *A. A. A. S.* XXXVI Meeting, 1887, p. 254.
Presence in Ostracoderms, *Cricotus, Diadectes;* characters of brain cast in *Diadectes* and *Belodon.*

.1026 (Defeat of the Appropriation for a Zoölogical Park at
Nov. Washington.) *Amer. Nat.* Vol. XXII, 1888, pp. 918, 919.
22 Unsigned editorial. Cited by Frazer.

.1027 Sketches of the Cascade Mountains of Oregon. *Amer. Nat.*
Dec. Vol. XXII, 1888, pp. 996-1003, Pl. XIX and Pl. XXI, pub-
3 lished in Vol. XXIII.

.1028 (The National Attitude toward Scientific Research.) *Amer.*
Dec. *Nat.* Vol. XXII, 1888, pp. 1003-1005.
3 Unsigned editorial. Cited by Frazer.

.1029 Handbuch der Palæontologie of Zittel. *Amer. Nat.* Vol.
Dec. XXII, 1888, pp. 1018, 1019.
3 Handbuch der Palæontologie, Band III, Teleostei (finis) et Batrachia, 1888.

.1030 Schlosser on Carnivora. *Amer. Nat.* Vol. XXII, 1888, pp.
Dec. 1019, 1020.
3 Review of: Die Affen, Lemur, Chieropteren, Insectivoren, Marsupialia, Creodonten u. Carnivoren des Europaischen Tertiärs, von Max Schlosser, Abtheil. II, 1888.

.1031 The Artiodactyla. *Amer. Nat.* Vol. XXII, 1888, pp. 1079-
Dec. 1095, Pls. XXV-XXVIII and figs. 1-6; Vol. XXIII, 1889,
26 pp. 111-136, Pls. III-VII and figs. 7-21.
A modified form of 974. Diagnosis of order, key to fami-

lies and their phylogenetic relations; synopsis of genera in each family with illustrations of principal types.

.1032 *Goniopholis* in the Jurassic of Colorado. *Amer. Nat.* Vol.
Dec. XXII, 1888, pp. 1106, 1107.
26 *Amphicotylus* Cope = *Goniopholis* Owen; skull of *G. lucasii* described.

.1033 A Horned Dinosaurian Reptile. *Amer. Nat.* Vol. XXII,
Dec. 1888, pp. 1108, 1109.
26 Note upon Prof. Marsh's articles on Ceratops in *Amer. Journ. Sci.* Dec., 1888. Probably identical with an unnamed disosaur described by Cope in 1877.

.1034 Broca's Convolution in the Apes. *Amer. Nat.* Vol. XXII,
Dec. 1888, p. 1124.
26 Criticism on Hervé's article in Bull. Soc. d'Anthropol. de France, April, 1888.

.1035 Reply to Mrs. M. M. E. on Marriage Time-Contracts. *Open*
Dec. *Court* Vol. II, No. 70, Dec. 27, 1888, pp. 1387-1388.
27

1889.1036 The Batrachia of North America. *Bull. U. S. Nat. Museum,* No. 34, 1889, 525 pp., LXXXVI Pls. and 119 figs.
This work still occupies the field as the only comprehensive treatise on North American amphibians.

.1037 The Mechanical Origin of the Hard Parts of the Mam-
Jan. malia. *Amer. Nat.* Vol. XXIII, 1889, pp. 71-73.
Abstract of 1062.

.1038 Evolution of Man. *Brooklyn Times,* Jan. 14, 1889, p. 3.
Jan. Lecture before Brooklyn Unitarian Church.
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.1039 Woman Suffrage. *Pop. Sci. Monthly* Vol. XXXIV, 1889,
Feb. pp. 558, 559.

.1040 Mrs. M. M. E. on Marriage Contracts. *Open Court* Vol.
Feb. II, No. 77, p. iii of cover; Feb. 14, 1889.
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.1041 (The American Society of Naturalists.) *Amer. Nat.* Vol.
March XXIII, 1889, pp. 32, 33.
1 Unsigned editorial. Cited by Frazer.

.1042 Catalogue of the Fossil Reptilia and Batrachia of the British
March Museum. Pt. I, by Dr. Lydekker. *Amer. Nat.* Vol. XXIII,
1 1889, p. 43.
Review.

.1043 March 14 What was Matriarchy? *Open Court,* Vol. III, No. 81, pp. 1518, 1519.

.1044 March 21 Ethical Evolution. *Open Court,* Vol. III, No. 82, pp. 1523-1529.

.1045 April 12 The Age of the Denver Formation. *Science,* Vol. XIII, No. 323, April 12, 1889, p. 290.

.1046 May 15 The Descent of Man. *Modern Science Essayist,* Vol. I, No. 7, 1889, pp. 161-170, and 175.

.1047 May 30 The Need of an Academic Chair for the Teaching of Evolution. *Open Court,* Vol. III, No. 92, p. 1650.

.1048 May 31 On the Mammalia obtained by the Naturalist Exploring Expedition to Southern Brazil. *Amer. Nat.* Vol. XXIII, 1889, pp. 128-150.

.1049 May 31 The Vertebrate Fauna of the Equus Beds. *Amer. Nat.* Vol. XXIII, 1889, pp. 160-165.

Lists of species from Silver Lake, Oregon, from southwest Texas, valley of Mexico, and from (Washtuckua Lake) Whitman Co., Washington; *Alces brevitrabalis* and *semipalmatus, Cariacus ensifer* described from the last locality.

.1050 June 1 A Review of the North American Species of *Hippotherium. Proc. Amer. Philos. Soc.* Vol. XXVI, 1889, pp. 429-458, three plates.

.1051 June 28 (The Post-Darwinians.) *Amer. Nat.* Vol. XXIII, 1889, pp. 136, 137.

Editorial.

.1052 June 28 Credner on *Palæohatteria. Amer. Nat.* Vol. XXIII, 1889, pp. 148, 149 (bis).

Critical review of Credner's paper.

1053. June 28 Brongniart and Döderlein on Xenacanthina. *Amer. Nat.* Vol. XXIII, 1889, pp. 149, 150.

Review of: Études sur le terrain Houillier de Commentry, par C. Brongniart et E. Sauvage, and Döderlein's article in the "Zoologischer Anzeiger," March, 1889.

.1054 June 28 The Vertebrata of the Swift Current River, II. *Amer. Nat.* Vol. XXIII, 1889, pp. 151-155.

Preliminary notice of additional collections obtained in

1888. *"Chalicotherium" bilobatum* n. sp., *Haplacodon* gen. et. sp. nov. five new species of White River mammalia.

.1055 July 25 Mr. Lydekker on *Phenacodus* and the Athecæ. *Nature*, Vol. XL, July 25, 1889, p. 298.

.1056 Aug. 15 The Proboscidia. *Amer. Nat.* Vol. XXIII, 1889, pp. 191-211, Pls. IX-XVI, figs. 1-9. Abstract, "Prof. Cope on the *Proboscidea*," *Geol. Mag.* Decade 3, Vol. VI, pp. 438-448, Pl. XIII, figs. 1-8.

Synopsis of characters and affinities, key to families and genera, list of species and key to those of North America; phylogeny; illustrations of several Tertiary American Mastodons and comparative diagrams of skulls of American and Old World Proboscideans.

.1057 Aug. 15 [Original Research in Pennsylvania.] *Amer. Nat.* Vol. XXIII, 1889, pp. 243, 244.

Unsigned editorial. Cited by Frazer.

.1058 Aug. 15 [The U. S. National Academy.] *Amer. Nat.* Vol. XXIII, 1889, pp. 244, 245.

Unsigned editorial. Cited by Frazer.

.1059 Aug. 15 [The American Society of Psychical Research.] *Amer. Nat.* Vol. XXIII, 1889, p. 245.

Unsigned editorial. Cited by Frazer.

.1060 Aug. 15 An Intermediate Pliocene Fauna. *Amer. Nat.* Vol. XXIII, 1889, pp. 253, 254.

Collection sent in by Duncan from "Oregon Desert." *Hippotherium relictum* n. sp. described. (The collection appears to be an admixture of specimens from two or more formations. W. D. M.)

.1061 Aug. 15 Storms on the Adhesive Disk of *Echeneis*. *Amer. Nat.* Vol. XXIII, 1889, pp. 254, 255.

Review of: Paper by Storms in Ann. & Mag. Nat. Hist. Ser. 6, Vol. II, p. 67.

.1062 Sept. The Mechanical Causes of the Development of the Hard Parts of the Mammalia. *Journ. Morph.* Vol. III, 1889, pp. 137-290, Pls. IX-XVI, figs. 1-93.

For abstract see 1037.

.1063 Sept. 11 Note on *Hippotherium rectidens*. *Proc. Amer. Philos. Soc.* Vol. XXVI, 1889, p. 458.

.1064 Nov. 18 An Outline of the Philosophy of Evolution. *Proc. Amer. Philos. Soc.* Vol. XXVI, 1889, pp. 495-505.

.1065 On a Species of *Plioplarchus* from Oregon. *Amer. Nat.* Vol.
Nov. XXIII, 1889, pp. 625, 626.
18 *P. septemsipinosus* n. sp. from shales near Van Horn's ranch, John Day R., Oregon. Discussion of geologic age of these shales. (Now referred to the Mascall; see Merriam 1901, Bull. Dept. Geol. Univ. Cal. Vol. II, p. 308).

.1066 On a New Genus of Triassic Dinosauria. *Amer. Nat.* Vol.
Nov. XXIII, 1889, p. 626.
18 *Cœlophysis* gen. nov. based upon three species from the Triassic of New Mexico previously referred to *Coelurus* Marsh and to *Tanystrophaeus* von Meyer.

.1067 Vertebrata of Swift Current River, No. III. *Amer. Nat.*
Nov. Vol. XXIII, 1889, pp. 628, 629.
18 Additional note describing three new species. See 1054.

.1068 Lamarck versus Weisman. *Nature* Vol. XLI, November 28,
Nov. 1889, p. 79.
28

.1069 [A National Flower.] *Amer. Nat.* Vol. XXIII, 1889, pp.
Dec. 484, 485.
1 Unsigned editorial. Cited by Frazer. Suggests the Mountain Laurel, or still better the Tulip-tree.

.1070 [Science in Newspapers.] *Amer. Nat.* Vol. XXIII, 1889, p.
Dec. 485.
1 Unsigned editorial. Cited by Frazer.

.1071 Marsh on Cretaceous Mammalia. *Amer. Nat.* Vol. XXIII,
Dec. 1889, pp. 490, 491.
1 Critical review of: Discovery of Cretaceous Mammalia, by O. C. Marsh, Amer. Journ. Sci. 1889, p. 81.

1890.1072 Syllabus of a Course of Lectures on Geology and Paleontology. Part I—Geology. Ferris Bros., Philadelphia, 8vo., 1890, 49 pp., 9 figs.

.1073 Two Perils of the Indo-European. *Open Court* Vol. III,
Jan. pp. 2052-2054; 2070, 2071.
3 This article appeared successively January 3 and January 30, 1890.

.1074 The Edentata of North America. *Amer. Nat.* Vol. XXIII,
Jan. 1889, pp. 657-664, Pls. XXXI, XXXII, figs. 1, 2.
5 Synopsis of suborders and families; key to genera of Megatheriidæ, and Glyptodontidæ; phylogeny. Figures of *Caryoderma* etc. [*Caryoderma* is now known to be a tortoise.]

.1075 Pohlig on *Elephas antiquus*. *Amer. Nat.* Vol. XXIII, 1889,
Jan. pp. 712, 713.
5 Review of Monographie der *Elaphas antiquus*, Falc., führen-

den Travertine Thüringens, ihrer Fauna und Flora. Theil I, *Nova Acta* Vol. LIII, 1888, s. 259.

.1076 The Horned Dinosauria of the Laramie. *Amer. Nat.* Vol.
Jan. XXIII, 1889, pp. 715-717, Pls. XXXIII, XXXIV.
5 Additional notes on *Monoclonius,* with figures or horn cores in three species, two of them new. Family Agathaumantidæ.

.1077 (Charges against the methods of the Paleontological Depart-
Jan. ment of the U. S. Geological Survey.) *New York Herald,*
12 Jan. 12 and 20, 1890.

.1078 [Opinions as to the Essential Nature of Organic Evolution.]
Feb. *Amer. Nat.* Vol. XXIV, 1890, pp. 49-51.
3 Unsigned editorial. Cited by Frazer.

.1079 Scientific Results of Explorations by the U. S. Fish Com-
Feb. mission steamer "Albatross," No. III—Report on the
5 Batrachians and Reptiles collected in 1887-1888. *Proc. U. S. Nat. Museum* Vol. XII, 1889, pp. 141-147. Separates Feb. 5, 1890.

.1080 (Exposition of Abuses among Geologists and Palæontol-
Feb. ogists.) *Amer. Nat.* Vol. XXIV, 1890, pp. 158, 159.
28 Unsigned editorial. Cited by Frazer.

.1081 A. Smith Woodward on *Cœlorhynchus* Agassiz. *Amer. Nat.*
Feb. Vol. XXIV, 1890, pp. 165, 166.
28 Review of Woodward's paper in Ann. & Mag. Nat. Hist. Sept. 1888. Unsigned. Cited by Hay.

.1082 Synopsis of the Families of Vertebrata. *Amer. Nat.* Vol.
March XXIII, 1889, pp. 849-877.
13 Family classification.

.1083 Notes on the Dinosauria of the Laramie. *Amer. Nat.* Vol.
March XXIII, 1889, pp. 904-906.
13 *Pteropelyx grallipes* gen. et sp. nov. (Trachodont, Judith River); notes on Agathaumidæ.

.1084 [Comment on Dr. Lamb's "Olecranon perforation."] *Amer.*
April *Anthropol.* Vol. III, 1890, p. 174.

.1085 [The Yellowstone Park.] *Amer. Nat.* Vol. XXIV, 1890,
April pp. 255, 256.
3 Unsigned editorial. Cited by Frazer.

.1086 New Hand-books of Paleontology. *Amer. Nat.* Vol. XXIV,
April 1890, pp. 259-261.
3 Review of: Elemente der Paleontologie, von Steinmann und Döderlein, 1890: Handbuch der Paleontologie, Abth. 1, Band III, Lief 3, Reptilien, von Prof. K. A. v. Zittel, 1889: Manual

of Paleontology for the use of Students, by R. A. Nicholson and R. Lydekker, 2 vols., 1889.

.1087 Seeley's Researches on the Organization, Structure and
April Classification of the Fossil Reptilia. *Amer. Nat.* Vol. XXIV,
5 1889, pp. 271-273.

Critical review of: On *Protorosaurus speneri* von Meyer, Philos. Trans. Roy. Soc. 1887; On *Pariasaurus bombidens* Owen., Philos. Trans. Roy. Soc. 1888; On the Anomodont Reptiles and their Allies, Philos. Trans. Roy. Soc. 1889.

.1088 (Original Research in the United States.) *Amer. Nat.* Vol.
April XXIV, 1890, p. 358.
25 Unsigned editorial. Cited by Frazer.

.1089 Tortoises sold in the Markets of Philadelphia. *Amer. Nat.*
April Vol. XXIV, 1890, p. 374.
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.1090 The Silver Lake of Oregon and its Region. *Amer. Nat.*
May Vol. XXIII, 1889, pp. 970-982, Pls. XL, XLI, and fig. 1.
10 Notes upon journey; recent fauna; Fossil Lake locality; list of fossil vertebrates.

.1091 (The Age of the Larami.) *Bull. Geol. Soc. Amer.* Vol. I,
May 1890, p. 532. *Amer. Nat.* Vol. XXIV, 1890, p. 569.
27 Certain remarks by Lester F. Ward, J. J. Stevenson and E. D. Cope at meeting of Geological Society of America.

.1092 The Homologies of the Fins of Fishes. *Amer. Nat.* Vol.
June XXIV, 1890, pp. 401-423, Pls. XIV-XVIII, figs. 1-9.

Relation of fins to legs, relation of fins to each other, nature of the supports of median fins, caudal fin and its supports.

.1093 (The Proposed Classes of the U. S. National Academy of
June Sciences.) *Amer. Nat.* Vol. XXIV, 1890, pp. 460, 461.
4 Unsigned editorial. Cited by Frazer.

.1094 (The Philadelphia Meeting of the International Congress of
June Geologists.) *Amer. Nat.* Vol. XXIV, 1890, pp. 461, 462.
4 Unsigned editorial. Cited by Frazer.

.1095 Scott and Osborn on the Fauna of the Brown's Park Eocene.
June *Amer. Nat.* Vol. XXIV, 1890, pp. 470-472.
4 Review of: The Mammalia of the Unita Formation, Pts. I, II by W. B. Scott; Pts. III, IV, by H. F. Osborn, Trans. Amer. Philos. Soc. Vol. XVI, 1889.

.1096 (The proposed National University.) *Amer. Nat.* Vol.
July XXIV, 1890, pp. 548, 549.
15 Unsigned editorial. Cited by Frazer.

.1097 July 15 (International Geological Congress.) *Amer. Nat.* Vol. XXIV, 1890, pp. 549-551.
Unsigned editorial. Cited by Frazer.

.1098 July 15 [Honest Nomenclature.] *Amer. Nat.* Vol. XXIV, 1890, p. 551.
Unsigned editorial. Cited by Frazer.

.1099 July 15 (Note on the "two-rooted" teeth described by Prof. Marsh.) *Amer. Nat.* Vol. XXIV, 1890, p. 571.
Teeth of Ceratopsia are not really two-rooted; the appearance is produced by absorption of centre of root above successional tooth. *Dysganus* Cope 1876 was based on Ceratopsian teeth.

.1100 July 17 The return of Negroes to Africa. *Open Court,* Vol. III, 1890, p. 2110; Vol. IV, 1890, p. 2331.

.1101 July 19 On Inheritance in Evolution. *Amer. Nat.* Vol. XXIII, 1889, pp. 1058-1071.
Exposition of theories of heredity.

.1102 July 19 [Original Scientific Research in the University of Pennsylvania.] *Amer. Nat.* Vol. XXIII, 1889, p. 1088.
Unsigned editorial. Cited by Frazer.

.1103 Aug. 8 The Cetacea. *Amer. Nat.* Vol. XXIV, 1890, pp. 599-616, Pls. XX-XXIII, figs. 1-8.
Synopsis of characters, affinities, classification and phylogeny, list of extinct American Cetacea.

.1104 Sept. 3 The Extinct Sirenia. *Amer. Nat.* Vol. XXIV, 1890, pp. 697-702, Pls. XXV, XXVI, figs. 1-3.
Synopsis of families and genera; figures of some American forms.

.1105 Sept. 3 [Reading Habits of the American Public.] *Amer. Nat.* Vol. XXIV, 1890, pp. 747, 748.
Unsigned editorial. Cited by Frazer.

.1106 Sept. 3 Eimer on Evolution. *Amer. Nat.* Vol. XXIV, 1890, pp. 751-754.
Review of: Organic Evolution as the Result of the Inheritance of Acquired Characters, according to the Law of Organic Growth, by G. E. T. Eimer, 1890.

.1107 Sept. 3 Geddes and Thompson on the Evolution of Sex. *Amer. Nat.* Vol. XXIV, 1890, pp. 754-760.
Review of: The Evolution of Sex, by Prof. Patrick Geddes and J. Arthur Thompson. Unsigned. Cited by Frazer.

.1108 Sept. 3 Note on *Casteroides georguensis* Moore. *Amer. Nat.* Vol. XXIV, 1890, p. 772.
Unsigned. Cited by Hay. Founded on a lower canine of *Hippopotamus.*

.1109 Sept. 3 Snakes in Banana Bunches. *Amer. Nat.* Vol. XXIV, 1890, p. 782.

.1110 Oct. On the Material Relations of Sex in Human Society. *The Monist,* Vol. I, 1890, pp. 38-47.

.1111 Oct. 14 Newberry's Paleozoic Fishes of North America. *Amer. Nat.* Vol. XXIV, 1890, pp. 844-847.
Critical review of: The Paleozoic Fishes of North America, by John Strong Newberry, Monograph XVI, U. S. Geol. Survey, 1889.

.1112 Nov. 8 The Evolution of Mind. *Amer. Nat.* Vol. XXIV, 1890, pp. 899-913; 1000-1016.

.1113 Nov. 8 [Limitation in Scientific Work.] *Amer. Nat.* Vol. XXIV, 1890, p. 918-920.
Editorial.

.1114 Nov. 8 (New York's Electric Execution Law.) *Amer. Nat.* Vol. XXIV, 1890, p. 921.
Unsigned editorial. Cited by Frazer.

.1115 Nov. 8 Poulton on the Colors of Animals. *Amer. Nat.* Vol. XXIV, 1890, pp. 927-932.
Review of: The Colors of Animals, their Meaning and Use especially considered in the case of Insects, by E. B. Poulton. 1890.

.1116 Nov. 8 On Two New Species of Mustelidæ from the Loup Fork Miocene of Nebraska. *Amer. Nat.* Vol. XXIV, 1890, pp. 950-952.
Stenogale robusta sp. and *Brachypsalis pachycephalus* gen. et. sp. nov.

.1117 Nov. 8 Note on a Bison at Syracuse, New York. *Amer. Nat.* Vol. XXIV, 1890, p. 954.
=*Bos americanus.*

.1118 Nov. 8 On a New Species of Salamander from Indiana. *Amer. Nat.* Vol. XXIV, 1890, pp. 966, 967, figs. 1-7.
Gyrinophilus maculicandus.

.1119 Dec. The African in America. *Open Court,* Vol. IV, 1890, pp. 2399-2401.

.1120 Dec. 6 (Scientific Nomenclature.) *Amer. Nat.* Vol. XXIV, 1890, pp. 1047-1049.
Unsigned editorial. Cited by Frazer.

.1121 Dec. 6 On a New Dog from the Loup Fork Miocene. *Amer. Nat.* Vol. XXIV, 1890, pp. 1067, 1068.
Aelurodon compressus n. sp. Based upon a lower jaw in the Cope Collection and two rami in Mus. Comp. Zool., referred by Scott and Osborn to *Ae. hyænoides* Cope. Figure of skeleton of *Ae. saevus* in Cope Coll.

1891.1122 On Vertebrata from the Tertiary and Cretaceous Rocks of the North West Territory. I—The Species from the Oligocene or Lower Miocene Beds of the Cypress Hills. *Contrib. to Canadian Pal.* Vol. III, pp. 1-25, Pls. I-XIV.
Amia whiteavesiana, A. macrospondyla.; Rhineastis rhæas; Amiurus cancellatus, A. maconnellii: all new species.

.1123 Report of the Sub-Committee on the Cenozoic (Interior): Reports of the American Sub-Committees on Classification and Nomenclature (E. D. Cope, Reporter). *Congrès Géol. Internat. 4e* Sess. Londres, 1888, Appendix A, pp. A193-A210. (Published 1891).

.1124 Jan. 9 (The Tariff on Scientific Books.) *Amer. Nat.* Vol. XXIV, 1890, pp. 1169, 1170.
Unsigned editorial. Cited by Frazer.

.1125 Jan. 9 Dr. Leonhard Stejneger on *Bufo lentiginosus woodhousei*. *Amer. Nat.* Vol. XXIV, 1890, pp. 1204, 1205.

.1126 Feb. 21 On Two New Perissodactyles from the White River Neocene. *Amer. Nat.* Vol. XXV, 1891, pp. 47-49.
Menodus peltoceras, Cænopus simplicidens, n. sp. (Types now in Amer. Mus.)

.1127 Feb. 21 Discovery of Fish Remains in Ordovician Rocks. *Amer. Nat.* Vol. XXV, 1891, p. 137.
Unsigned. Cited by Hay. Notice of Walcott's preliminary announcement before Biol. Soc. Washington, Feb. 7, 1891.

.1128 March 26 Material Relations of Sex in Human Society. *Open Court* Vol. V, No. 187, March 26, 1891, p. 2748.

.1129 April 2 The Epiglottis in Colubrine Snakes. *Amer. Nat.* Vol. XXV, 1891, pp. 156, 157, one fig.

.1130 April 2 Professor Moll on Hypnotism. *Amer. Nat.* Vol. XXV, 1891, pp. 170, 171.
Review of: Hypnotism, by Albert Moll, 1890.

.1131 The Economic Relations of Sex. *Open Court* Vol. V,
May No. 193, May 7, 1891, pp. 2801, 2802.
7

.1132 (New National Parks.) *Amer Nat.* Vol. XXV, 1891,
May pp. 472, 473.
28 Unsigned editorial. Cited by Frazer.

.1133 On the Non-Actinopterygian Teleostomi. *Amer. Nat.* Vol.
May XXV, 1891, pp. 479-481.
28 Short discussion followed by a table giving superorders, orders, and families to show relationships.

.1134 [Prof. Karl Vogt and the Naturalists.] *Amer. Nat.* Vol.
June XXV, 1891, pp. 558, 559.
27 Editorial.

.1135 On the Structure of Certain Paleozoic Fishes. *Proc. A. A.*
July *A. S.* XXXIX Meeting, 1890, p. 336.
Macropetalichthys, Megalichthys, Platysomus and *Dendrodus* briefly considered.

.1136 The Relation of Mind to its Physical Basis. *Proc. A. A.*
July *A. S.* XXXIX Meeting, 1890, p. 378.
Abstract only.

.1137 Syllabus of Lectures on Geology and Paleontology. Part
July III—Paleontology of the Vertebrata. Ferris Bros., Phila-
8 delphia, 8vo., 1891, 90 pp., 60 figs.
See also 1390.

.1138 [Preoccupied Names.] *Amer. Nat.* Vol. XXV, 1891, pp. 640,
July 641.
31 Unsigned editorial. Cited by Frazer. Objection regarding *Menodus* as preoccupied by *Menodon.*

.1139 Catalogue of the Fossil Reptilia and Batrachia (Amphibia)
July in the British Museum, Parts II, III and IV. *Amer. Nat.*
31 Vol. XXV, 1891, pp. 644-646.
Review of: Catalogue of the Fossil Reptilia and Amphibia in the British Museum, by Richard Lydekker, Part II, 1889, Part III, 1889, Part IV, 1890. Criticism of classification and nomenclature adopted.

.1140 A. S. Woodward's Fossil Fishes. *Amer. Nat.* Vol. XXV,
July 1891, pp. 646, 647.
31 Review of: Catalogue of Fossil Fishes in the British Museum, by Arthur Smith Woodward, Part I, 1889; Part II, 1891.

.1141 Mrs. Bodington on Evolution. *Amer. Nat.* Vol. XXV, 1891,
July p. 647.
31 Review of: Studies in Evolution and Biology, by Alice
Bodington, 1890.

.1142 On some New Fishes from South Dakota. *Amer. Nat*
July Vol. XXV, 1891, pp. 654-658. Read under title, "On a
31 New Horizon of Fossil Fishes," before the A. A. A. S. XL
Meeting, 1891. Abstract only, Proc. A. A. A. S. XL Meeting,
1891, p. 258.
Gephyrura, Proballostomus, new genera described, three
species from Tertiary of Ree Hills, S. D.

.1143 The Liptoterna. *Amer. Nat.* Vol. XXV, 1891, pp. 685-693,
Sept. Pl. XVII, figs. 1-5.
11 Discussion of characters and affinities; synopsis of families
and genera. Astrapotherium and Homalodontotherium provisionally included. Based largely on Ameghino's "Mamiferos Fosiles de la Republica Argentina."

.1144 Anent Women's Waists. *Amer. Nat.* Vol. XXV, 1891, pp.
Sept. 717, 718.
11 Editorial.

.1145 (Marine Biological Laboratories.) *Amer. Nat.* Vol. XXV,
Sept. 1891, pp. 718-721.
11 Unsigned editorial. Cited by Frazer.

.1146 (Execution by Electricity.) *Amer. Nat.* Vol. XXV, 1891,
Sept. pp. 721, 722.
11 Unsigned editorial.

.1147 Ameghino on the Extinct Mammalia of Argentina. *Amer.*
Sept. *Nat.* Vol. XXV, 1892, pp. 725-727.
11 Review of: Contribucion al concimento de los mamiferos
fosiles de la Republica Argentina . . . por Florintino
Ameghino. Actes, Acad. nacional ciencias, Cordoba, T. VI,
1889.

.1148 Miller's North American Geology and Paleontology. *Amer.*
Sept. *Nat.* Vol. XXV, 1891, p. 729.
11 Review of: American Geology and Paleontology for the
Use of Amateur Students and Scientists, by S. A. Miller,
1889. Unsigned. Cited by Frazer.

.1149 Morris on Civilization. *Amer. Nat.* Vol. XXV, 1891, p. 730.
Sept. Review of: Civilization. A Historical Review of its Ele-
11 ments, by Charles Morris, 1890. Unsigned. Cited by Frazer.

.1150 Snakes in Banana Bunches. *Amer. Nat.* Vol. XXV, 1891,
Sept. p. 742.
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.1151 Morris' Aryan Race. *Amer. Nat.* Vol. XXV, 1891, pp. 812,
Oct. 813.
6 Review of: The Aryan Race: Its Origin and its Achievements, by Charles Morris 1888.

.1152 Boulenger on Rhynchocephalia, Testudinata, and Crocodilia.
Oct. *Amer. Nat.* Vol. XXV, 1891, pp. 813, 814.
6 Review of: Catalogue of the Chelonians, Rhynchocephalians and Emydosaurians in the British Museum, by G. A. Boulenger, 1889.

.1153 On a Skull of the *Equus excelsus* Leidy from the Equus
Oct. Beds of Texas. *Amer. Nat.* Vol. XXV, 1891, pp. 912, 913.
23 Read before the A. A. A. S. under the title, "On the Cranial Characters of *Equus excelsus*," and under that title in Proc. A. A. A. S. XL Meeting, 1891, p. 285.
First skull on record of an American fossil Equus.

.1154 (Tariff on Scientific Works.) *Amer. Nat.* Vol. XXV,
Nov. 1891, pp. 990, 991.
17 Unsigned editorial. Cited by Frazer.

.1155 [Recent Progress in the Discovery of the Phylogeny of
Nov. Man.] *Amer. Nat.* Vol. XXV, 1891, pp. 991, 992.
17 Editorial. Notice of Spy discoveries in Belgium, and *Homunculus* in Patagonia.

.1156 The California Cave Bear. *Amer. Nat.* Vol. XXV, 1891,
Nov. pp. 997-999, Pl. XXI.
17 Description, with figures, of *Arctotherium simum* skull.

.1157 More New Mammalia from the Eocene of Patagonia. *Amer.*
Nov. *Nat.* Vol. XXV, 1891, pp. 1000, 1001.
17 Comment on Ameghino's discoveries.

.1158 A New Species of Frog from New Jersey. *Amer. Nat.* Vol.
Nov. XXV, 1891, pp. 1017-1019.
17 *Rana virgatipes.*

.1159 On the Characters of some Paleozoic Fishes. *Proc. U. S.*
Dec. *Nat. Museum* Vol. XIV, 1891, pp. 447-463, Pls. XXVIII-
12 XXXIII.
New species of *Styptobasis, Hybodus, Ctenacanthus* and *Platysomus.* (2); cranial structure of *Macropetalichthys.* (7p.); pectoral limbs of *Holonema;* paired fins of *Megalichthys;* superorders of the non-actinopterygian Teleostomi.

.1160 (Recent Endowments for Scientific Research.) *Amer. Nat.*
Dec. Vol. XXV, 1891, pp. 1111, 1112.
22 Unsigned editorial. Cited by Frazer.

.1161 Flower and Lydekker's Mammals. *Amer. Nat.* Vol. XXV,
Dec. 1891, pp. 1116-1118.
22 Review of: An Introduction to the Study of Mammals, Living and Extinct, by W. H. Flower and R. Lydekker, 1891.

.1162 Color Patterns in *Cnemidophorus*. *Amer. Nat.* Vol. XXV,
Dec. 1891, pp. 1135, 1136.
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.1163 A Rorqual on the New Jersey Coast. *Amer. Nat.* Vol. XXV,
Dec. 1891, p. 1136.
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1892.1164 Vertebrate Fauna of the Alachua Clays, Florida. *Bull. U. S. Geol. Survey* No. 84, 1891, Correlation papers, Neocene, p. 130.

.1165 A Fin-Back Whale recently Stranded on the New Jersey
Jan. Coast. *Proc. Acad. Nat. Sci. Phila.* Vol. XLIV, 1891, pp.
5 474-478.

.1166 Alfred Russell Wallace. *Brooklyn Ethical Assoc., Evolution*
March *Series*, No. 1, March 1, 1892, 15 pp.
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.1167 The Age of the Staked Plains of Texas. *Amer. Nat.* Vol.
March XXVI, 1892, pp. 49, 50.
26 Pliocene: Blanco formation.

.1168 Definite vs. Fortuitous Variation in Animals and Plants.
March *Amer. Nat.* Vol. XXVI, 1892, pp. 89-91.
26 Abstract of remarks before Amer. Soc. of Naturalists, Dec. 30, 1891.

1169 A Critical Review of the Characters and Variations of the
March Snakes of North America. *Proc. U. S. Nat. Musuem* Vol.
28 XIV, 1892, pp. 589-694.

.1170 A Contribution to the Vertebrate Palæontology of Texas.
March *Proc. Amer. Philos. Soc.* Vol. XXX, 1892, pp. 123-131,
30 one fig. Reprint, "Report on the Palæontology of the Vertebrata," *Third Ann. Report, Geol. Survey, Texas*, 1891, pp. 251-259.

.1171 On *Tiaporus*, a New Genus of Teiidæ. *Proc. Amer. Philos.*
March *Soc.* Vol. XXX, 1892, pp. 132, 133, one plate.
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.1172 On the Habits and Affinities of the new Australian Mammal,
March *Notoryctes typhlops*. *Amer. Nat.* Vol. XXVI, 1892, pp.
31 121-128, Pls. IX, X.
Extracts from Stirling's memoir describing Notoryctes.

Trans. R. Soc. S. Austr., 1891, vol. xiv. Discussion of affinities. Regards it as more probably related to Chrysochloridæ.

Cope's genus *Bematiscus* established in a footnote to p. 127.

.1173 April 25 [Mongoose in the West.] *Amer. Nat.* Vol. XXVI, 1892, p. 236.

Unsigned editorial. Cited by Frazer.

.1174 April 27 On the Homologies of the Posterior Cranial Arches in the Reptilia. *Trans. Amer. Philos. Soc.* n. s. Vol. XVII, 1892, pp. 11-26, Pls. I-V and figs. 1-3. Separates April 27, 1892. Abstract, "The Homologies of the Cranial Arches of the Reptilia," *Amer. Nat.* Vol. XXVI, 1892, pp. 407, 408, Pls. XV-XVII.

.1175 April 29 [Rational Nomenclature.] *Amer. Nat.* Vol. XXVI, 1892, pp. 319, 320.

Unsigned editorial. Cited by Frazer.

.1176 May 1 Professor Marsh on Extinct Horses and Other Mammalia. *Amer. Nat.* Vol. XXVI, 1892, pp. 410-412.

Critical review of: On recent Polydactyle Horses, by O. C. Marsh, Amer. Journ. Sci., 1892, p. 339; and, A New Order of Extinct Mammalia, by O. C. Marsh, Amer. Journ. Sci., 1892, p. 445.

.1177 May 4 A Synopsis of the Species of the Teid Genus *Cnemidophorus*. *Trans. Amer. Philos. Soc.* n. s. Vol. XVII, 1892, pp. 27-52, Pls. VI-XIII. Separates May 4, 1892. Abstract, "Parallel Color-Patterns in Lizards," *Amer. Nat.* Vol. XXVI, 1892, p. 522, Pls. XVIII, XIX.

.1178 May 9 The Osteology of the *Lacertilia*. *Proc. Amer. Philos. Soc.* Vol. XXX, 1892, pp. 185-221, Pls. II-VI.

.1179 May 24 On some New and Little Known Paleozoic Vertebrates. *Proc. Amer. Philos. Soc.* Vol. XXX, 1892, pp. 221-229, Pls. VII, VIII.

.1180 May 27 On the Skull of the Dinosaurian *Lælaps incrassatus* Cope. *Proc. Amer. Philos. Soc.* Vol. XXX, 1892, pp. 240-245.

.1181 June 13 Remarks on the communication, "Ein fossiler Giftzahn," by Dr. F. Kinkelin. *Zool. Anz.* XV Jahrg., Nr. 393, 1892, s. 224.

.1182 July On Color Variations in certain Reptilia. *Proc. A. A. A. S.*, XL Meeting, 1891, pp. 320, 321.

.1183 July — On the Reduction of the Scapular and Pelvic Arches and Limbs in Lacertilia. *Proc. A. A. A. S.*, XL Meeting, 1891. p. 320.

In its finally developed form the paper is 1189.

.1184 Aug. — In the Texas Panhandle. *Amer. Geol.* Vol. X, 1892, pp. 131, 132.

.1185 Aug. 23 — A Contribution to a Knowledge of the Blanco Beds of Texas. *Proc. Acad. Nat. Sci. Phila.* Vol. XLIV, 1892, pp. 226-229. Abstract, "The Cenozoic Beds of the Staked Plains of Texas," *Proc. A. A. A. S.*, XLI Meeting, 1892, p. 177.

.1186 Sept. — Fourth Note on the Dinosauria of the Laramie. *Amer. Nat.* Vol. XXVI, 1892, pp. 756-758.

Manospondylus and *Claorhynchus*, new genera. Notes on *Agathaumas* based upon complete skeleton found by J. L. Wortman in South Dakota (subsequently referred to Hadrosaurus = Trachodon).

.1187 Sept. 1 — On a New Genus of Mammalia from the Laramie Formation. *Amer. Nat.* Vol. XXVI, 1892, pp. 758-762, Pl. XXII. Abstract, "On a New Form of Marsupial from the Laramie Formation," *Proc. A. A. A. S.*, XLI Meeting, 1892, p. 177.

Description of *Thlæodon padanicus* gen. et sp. nov.

.1188 Oct. — The Future of Thought in America. *The Monist* Vol. III, 1892, No. 1, pp. 23-29.

.1189 Nov. — On Degenerate Types of Scapular and Pelvic Arches in the Lacertilia. *Journ. Morph.* Vol. VII, 1892, pp. 223-244, Pl. XIII.

Read before the Nat. Acad. Sci. Nov. 10, 1891.

.1190 Nov. 1 — [Man's Powers of Observation.] *Amer. Nat.* Vol. XXVI, 1892, p. 931.

Unsigned editorial. Cited by Frazer.

.1191 Nov. 1 — Crook on Saurodontidæ from Kansas. *Amer. Nat.* Vol. XXVI, 1892, pp. 941, 942.

Critical review of: Ueber einige fossile Knochenfische der Mittleren Kreide von Kansas, von Alja Robinson Crook, Palæontographica, Bd. XXXIX, 1892, s. 107.

.1192 Nov. 1 — A New Species of *Eutænia* from Western Pennsylvania. *Amer. Nat.* Vol. XXVI, 1892, pp. 964, 965, one fig.

Eutænia brachystoma.

.1193 Nov. 29 — On the Permanent and Temporary Dentitions of certain Three-toed Horses. *Amer. Nat.* Vol. XXVI, 1892, pp. 942-944, Pls. XXV, XXVI. *Proc. Acad. Nat. Sci. Phila.* Vol. XLIV, 1892, pp. 325, 326.

The Proc. Acad. Nat. Sci. Phila. appeared about three weeks later and lacks the plates and their explanation. *Anchippus, Parahippus, Hypohippus* and *Merychippus* appear to be the temporary dentition of *Hippotherium* and *Protohippus*. *Protohippus placidus* = *Hipparion gratum*.

.1194 Nov. 29 A Hyaena and other Carnivora from Texas. *Proc. Acad. Nat. Sci. Phila.* Vol. XLIV, 1892, pp. 326, 327. Reprint. *Amer. Nat.* Vol. XXVI, 1892, pp. 1028, 1029.

Borophagus a hyaena, *Canimartes* a new musteline, *Felis hillanus* (earliest true cat in North America).

.1195 Nov. 29 The Batrachia and Reptilia of Northwestern Texas. *Proc. Acad. Nat. Sci. Phila.* Vol. XLIV, 1892, pp. 331-337.

Collection from the Staked Plains.

.1196 Nov. 29 American Devonian Fishes in Belgium. *Amer. Nat.* Vol. XXVI, 1892, p. 1025.

Notice of a paper by M. Lohest in Ann. Soc. geol. de Belgique, T. XVI, p. lvii. Unsigned. Cited by Hay.

.1197 Dec. 1 The Fauna of the Blanco Epoch. *Amer. Nat.* Vol. XXVI, 1892, pp. 1058, 1059.

Brief abstract of paper read before the Nat. Acad. Sci. in 1892.

1893.1198 Jan. 2 On the Phylogeny of the Vertebrata. *Proc. Amer. Philos. Soc.* Vol. XXX, 1892, pp. 278-281.

.1199 Jan. 3 On some Points in the Kinetogenesis of the Limbs of Vertebrates. *Proc. Amer. Philos. Soc.* Vol. XXX, 1892, pp. 282-285.

.1200 Jan. 6 On False Elbow Joints. *Proc. Amer. Philos. Soc.* Vol. XXX, 1892, pp. 285-291, Pls. IX, X.

.1201 Jan. 11 [The Antivivisectionists in Pennsylvania.] *Amer. Nat.* Vol. XXVII, 1893, p. 26.

Unsigned editorial. Cited by Frazer.

.1202 Feb. 4 [The Law of Priority in Nomenclature.] *Amer. Nat.* Vol. XXVII, 1893, pp. 134, 135.

Unsigned editorial. Cited by Frazer.

.1203 Feb. 4 A Remarkable Artiodactyle from the White River Epoch. *Amer. Nat.* Vol. XXVII, 1893, pp. 147, 148, Pls. I, II.

Review of Osborn's and Wortman's description of *Protoceras celer* in Bull. Amer. Mus. Nat. Hist. Vol. IV, 1892, pp. 359-372.

.1204 On a New Spade-Foot from Texas. *Amer. Nat.* Vol.
Feb. XXVII, 1893, pp. 155, 156.
4 *Spea laticeps.*

.1205 [The Geological Survey of Illinois.] *Amer. Nat.* Vol.
March XXVII, 1893, p. 238.
4 Unsigned editorial. Cited by Frazer.

.1206 [Mortality of the English Sparrow.] *Amer. Nat.* Vol.
March XXVII, 1893, p. 239.
4 Unsigned editorial. Cited by Frazer.

.1207 Correlation Papers of the U. S. Geological Survey—Neocene.
March *Amer. Nat.* Vol. XXVII, 1893, pp, 246-248.
4 Review of: Bulletin, U. S. Geol. Survey No. 84—Correlation Papers Neocene, by W. H. Dall and G. D. Harris, 1892. Unsigned. Cited by Frazer.

.1208 Cary on the Evolution of Foot Structure. *Amer. Nat.*
March Vol. XXVII, 1893, pp. 248-250.
4 Review of: A Study in Foot Structure, by Austin Cary, Amer. Journ. Morph., Dec., 1892, p. 305.

.1209 Earle on the Species of Coryphodontidæ. *Amer. Nat.*, Vol.
March XXVII, 1893, pp. 250-252.
4 Critical review of: Revision of the Species of *Coryphodon*. Bull. Amer. Museum Nat. Hist., Vol. IV, Art. XII, pp. 149-166, Oct. 18, 1892. Takes exception to Earle's reduction of many species to synonymy.

.1210 The Vertebrate Fauna of the Ordovician of Colorado. *Amer.*
March *Nat.* Vol. XXVII, 1893, pp. 268, 269.
4 Unsigned. Cited by Hay. Review of Walcott's article in Bull. Geol. Soc. Amer. Vol. III, pp. 153-172.

.1211 A New Extinct Species of Cyprinidæ. *Proc. Acad. Nat.*
March *Sci. Phila.* Vol. XLV, 1893, pp. 19, 20. *Aphelichthys lindahlii*
14 N. Sp. from Pulaski Co., Illinois.

.1212 The Lynching at Paris, Texas. *Open Court* Vol. VII, No.
March 291, March 23, 1893, p. 3606.
23

.1213 The Genealogy of Man. *Amer. Nat.* Vol. XXVII, 1893,
April pp. 321-335, Pl. IX, and figs. 1-9.
5 Discusses derivation of man and anthropoid apes from Eocene Lemuroidea, the monkeys and the modern lemurs being both side branches; characters of the Spy race (Neanderthaloids).

.1214 [Book Publication in America.] *Amer. Nat.* Vol. XXVII,
April 1893, p. 359.
5 Unsigned editorial. Cited by Frazer.

.1215 April 5 Animal Coloration. *Amer. Nat.* Vol. XXVII, 1893, pp. 371-374, figs. 1-3.

Review of: Animal Coloration, an Account of the Principal Facts and Theories relating to the Colors and Markings of Animals, by Frank E. Beddard, 1892. Unsigned. Under Cope in index of volume.

.1216 April 5 Fossil Reptiles from the Parana. *Amer. Nat.* Vol. XXVII, 1893, pp. 376, 377.

Comment on Ambrosetti's article in Boletin, Acad. nacional de Ciencias, Cordoba.

1217. April 18 A Contribution to the Herpetology of British Columbia. *Proc. Acad. Nat. Sci. Phila.* Vol. XLVI, 1893, pp. 181-184.

.1218 May A Preliminary Report on the Vertebrate Palæontology of the Llano Estacado. *Fourth Ann. Report, Geol. Survey, Texas,* 1892, pp. 1-89, Pls. I-XXIII. Separates, May, 1893. Abstract, "The Vertebrate Palæontology of the Llano Estacado," *Amer. Nat.* Vol. XXVII, 1893, pp. 811-812.

.1219 May 23 Description of the Lower Jaw of *Tetrabelodon shepardii* Leidy. *Proc. Acad. Nat. Sci. Phila.* Vol. XLV, 1893, pp. 202-204. Abstract, *Amer. Nat.* Vol. XXXVII, 1893, p. 473.

.1220 May 25 [The Geological Survey of Georgia.] *Amer. Nat.* Vol. XXVII, 1893, p. 450.

Unsigned editorial. Cited by Frazer.

.1221 May 25 [The Exhibition of Monstrosities.] *Amer. Nat.* Vol. XXVII, 1893, pp. 450, 451.

Unsigned editorial. Cited by Frazer.

.1222 May 25 Prodromus of a New System of the Non-venomous Snakes. *Amer. Nat.* Vol. XXVII, 1893, pp. 477-483.

.1223 June 15 Evolution of the Colors of North American Land Birds. *Amer. Nat.* Vol. XXVII, 1893, pp. 547-549.

Review of: Evolution of the Colors of North American Land Birds by Charles A. Keeler, Occasional papers, Calif. Acad. Sci., III, 1893.

.1224 June 15 Wright's Man and the Glacial Period. *Amer. Nat.* Vol. XXVII, 1893, pp. 550-553.

Review of: Man and the Glacial Period, by G. Frederick Wright, 1892.

.1225 June 15 A Supposed New Order of Gigantic Fossils from Nebraska. *Amer. Nat.* Vol. XXVII, 1893, pp. 559, 560.

Daimonelix. Review of article by E. H. Barbour. These objects are regarded by Cope as rodent burrows.

.1226 The Foundations of Theism. *The Monist* Vol. III, 1893,
July pp. 623-639.

.1227 Calderwood on Mental Evolution. *Amer. Nat.* Vol. XXVII,
July 1893, pp. 654, 655.
24 Review of: Evolution and Man's Place in Nature, by Henry Calderwood, 1893.

.1228 The Relation of Consciousness to its Physical Basis. *Religo-*
Sept. *Philosophical Journ.* n. s. Vol. IV, 1893, pp. 293, 294.
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.1229 The Effeminization of Man. *Open Court* Vol. VII, Oct. 26,
Oct. 1893, p. 3847.
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.1230 [The Field Museum of Chicago.] *Amer. Nat.* Vol. XXVII,
Oct. 1893, p. 886.
31 Unsigned editorial. Cited by Frazer.

.1231 [Duplication of Names of Post Offices.] *Amer. Nat.* Vol.
Oct. XXVII, 1893, pp. 886, 887.
31 Unsigned editorial. Cited by Frazer.

.1232 A New Pleistocene Saber-tooth. *Amer. Nat.* Vol. XXVII,
Oct. 1893, pp. 896, 897.
31 *Dinobastis serus* gen. et sp. nov. from Pleistocene of Oklahoma.

.1233 [Specimens in the Mails.] *Amer. Nat.* Vol. XXVII, 1893,
Oct. pp. 979, 980.
31 Unsigned editorial. Cited by Frazer.

.1234 [The Pronunciation of Arkansas.] *Amer. Nat.* Vol. XXVII,
Oct. 1893, pp. 980, 981.
31 Unsigned editorial. Cited by Frazer.

.1235 The Report of the Death Valley Expedition. *Amer. Nat.*
Oct. Vol. XXVII, 1893, pp. 990-995.
31 Review of: The Death Valley Expedition: A Biological Survey of Parts of California, Nevada, Arizona and Utah, Part II. North American Fauna, No. 7, 1893.

.1236 On *Symmorium*, and the Position of the Cladodont Sharks.
Nov. *Amer. Nat.* Vol. XXVII, 1893, pp. 999-1001.
24 On basis of pectoral fin structure, Cladodontidae are removed from Ichthyotomi and placed among the Acanthodii.

.1237 Forsyth Major and Rose on the Theory of Dental Evolu-
Nov. tion. *Amer. Nat.* Vol. XXVII, 1893, pp. 1014-1016.
24 Critical comment on recent articles by these writers.

.1238 Dec. 7 On the Genus *Tomiopsis*. *Proc. Amer. Philos. Soc.* Vol. XXXI, 1893, pp. 317, 318.

.1239 Dec. 13 The Color Variations of the Milk Snake. *Amer. Nat.* Vol. XXVII, 1893, pp. 1066-1071, Pls. XXIV-XXVIII.

.1240 Dec. 13 [College and University Publications.] *Amer. Nat.* Vol. XXVII, 1893, p. 1072.
Unsigned editorial. Cited by Frazer.

.1241 Dec. 13 Fritsch's Fauna of the Gaskohle of Bohemia. *Amer. Nat.* Vol. XXVII, 1893, pp. 1079-1081, Pls. XXIX, XXX and one fig.
Critical review of: Fauna der Gaskohle und Kalkstein der Permformations Böhmes von Anton Fritsch, Band II, Heft 4, 1889; Band III, Hefts I and II, 1893.

.1242 Dec. 13 Cladodont Sharks of the Cleveland Shale. *Amer. Nat.* Vol. XXVII, 1893, p. 1083.
Unsigned. Cited by Hay. Review of Claypole's paper in Amer. Geol., May, 1893.

.1243 Dec. 23 Second Addition to the Knowledge of the Batrachia and Reptilia of Costa Rica. *Proc. Amer. Philos. Soc.* Vol. XXXI, 1893, pp. 333-347.

894.1244 Jan. 25 On Three New Genera of *Characinidæ*. *Amer. Nat.* Vol. XXVIII, 1894, p. 67.
Asiphonichthys, Chorimycterus, Diapoma, from upper Jacuhy R., Rio Grande do Sul, Brazil.

.1245 Jan. 30 On a collection of Batrachia and Reptilia from Southwest Missouri. *Proc. Acad. Nat. Sci. Phila.* Vol. XLV, 1893, pp. 383-385.
Ozark Mountain country.

.1246 Jan. 30 On the Batrachia and Reptilia of the Plains at Latitude 36° 30′. *Proc. Acad. Nat. Sci. Phila.* Vol. XLV, 1893, pp. 386, 387.

.1247 Jan. 30 Fossil Fishes from British Columbia. *Proc. Acad. Nat. Sci. Phila.* Vol. XLV, 1893, pp. 401, 402.
Amyzon brevipinne N. Sp.

.1248 Feb. 27 Heredity in the Social Colonies of the Hymenoptera. *Proc. Acad. Nat. Sci. Phila.* Vol. XLV, 1893, pp. 436-438.

.1249 On the Fishes obtained by the Naturalist Expedition in Rio
March Grande do Sul. *Proc. Amer. Philos. Soc.* Vol. XXXIII,
3 1894, pp. 84-108, Pls. IV-IX.

Forty-two species listed, mainly Characinidae (3 new genera and 9 new species), Siluridae (6 new species), and Cichlidae (2 new species).

.1250 On the Structure of the Skull in the Plesiosaurian Reptilia,
March and on Two New Species from the Upper Cretaceous. *Proc.*
6 *Amer. Philos. Soc.* Vol. XXXIII, 1894, pp. 109-113, Pl. X, one fig. Separates March 6, 1894.

.1251 The Energy of Evolution. *Amer. Nat.* Vol. XXVIII,
March 1894, pp. 205-219.
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.1252 An Examination of Weismannism. *Amer. Nat.* Vol. XXVIII,
March 1894, pp. 257-259.
8 Review of: An Examination of Weismannism, by George John Romanes, 1893.

.1253 Extinct Monsters. *Amer. Nat.* Vol. XXVIII, 1894, pp. 259-
March 262, figs. 1, 2.
8 Review of: Extinct Monsters. A popular Account of some of the Larger Forms of Ancient Animal Life, by Rev. H. N. Hutchinson, 1893.

.1254 The Origin of Structural Variations. *New Occasions* Vol.
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Transferred from Condylarthra to Amblypoda forming, with the Pantolambdidæ, a primitive suborder Taligrada of the Amblypoda. This is the last original contribution to mammalian paleontology published by Professor Cope before his death. It is largely in the nature of a forecast and has been completely verified by subsequent discoveries, save for the supposed relationship to the Artiodactyla.

.1387 April 26 — On New Paleozoic Vertebrata from Illinois, Ohio and Pennsylvania. *Proc. Amer. Philos. Soc.* Vol. XXXVI, 1897, pp. 71-91, Pls. I-III.

.1388 June — Toxodontia. *Amer. Nat.* Vol. XXXI, 1897, pp. 485-492.
Classification and principal characters of the orders, families and genera, based upon Ameghino's researches.

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Editorial.

1898.1390 Syllabus of Lectures on the Vertebrata. With an Introductory by Henry Fairfield Osborn. University of Pennsylvania, 8vo. 1898, pp. iii-xxxv; 1-35; 66 figs.
For the original issue see 1072 and 1137.

.1391 Aug. Letter to Professor Mudge. *University Geol. Survey of Kansas,* Vol. IV, Pt. I, pp. 29, 30.
See Hay 1898 A for Note.

1899.1392 Feb. 4 Vertebrate Remains from Port Kennedy Bone Deposit. *Journ. Acad. Nat. Sci. Phila.* Ser. 2, Vol. XI, 1899, pp. 193-267, Pls. XVIII-XXI, and figs. 1-3.

.1393 May 26 Contributions to the Herpetology of New Granada and Argentina, with Descriptions of New Forms. *Scientific Bulletin, No. 1, Philadelphia Museums,* 22 pp. IV Pls. May 26, 1899.
Including a new lacertilian genus, *Heterodonium* from Colombia and a synopsis of the genus *Himantodes.*

1900.1394 Aug. 10 The Crocodilians, Lizards and Snakes of North America. *Report, U. S. Nat. Museum,* 1898, pp. 153-1270, Pls. I-XXXVI, figs. 1-347. Separates Aug. 10, 1900.
Although full of inaccuracies this volume is the standard authority and the only comprehensive treatise on North American reptiles.

1915.1395 Hitherto Unpublished Plates of Tertiary Mammalia and Permian Vertebrata. (With W. D. Matthew.) Prepared under the Direction of Edward Drinker Cope for the U. S. Geological Survey of the Territories, with Descriptions of Plates by William Diller Matthew. *American Museum of Natural History, Monograph Series No. 2.* Published and Distributed with the cooperation of the United States Geological Survey by the American Museum of Natural History, 1915.
These plates were prepared under Professor Cope's direction about 1881-3 to illustrate the final volumes of his reports on fossil vertebrates for the Hayden Survey (U. S. Geol. and Geogr. Survey of the Territories) which were never published. The titles appear on the plates, but no manuscript or plate descriptions pertaining to them were found among Professor Cope's papers. The joint publication of the plates as specified in the title was arranged through the efforts of Professor Henry Fairfield Osborn. Nearly all the specimens illustrated are in the Cope Collection, American Museum of Natural History.

Jacques Loeb

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BIOGRAPHICAL MEMOIRS

VOLUME XIII - FOURTH MEMOIR

BIOGRAPHICAL MEMOIR

OF

JACQUES LOEB

1859—1924

BY

W. J. V. OSTERHOUT

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1930

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JACQUES LOEB.

BY W. J. V. OSTERHOUT.

I.

If I venture to write of Jacques Loeb, it is not to create a portrait but only to set forth facts to aid those who would follow in his footsteps. In this I bespeak the charity of the reader. And if the writing achieve any part of its purpose it is because of many who in loving veneration gave loyal aid.

Loeb's ancestors were among those illuminati who forsook Portugal on account of the intolerance of the Inquisition: they settled at Mayen in the Rhine province several generations before he was born. His father, Benedict Loeb, was an importer, a man of simple tastes, more interested in science (especially in physics, mathematics, and geology), in literature, and in collecting books than in business. He was extremely reserved, and much of an æsthete. He married Barbara Isay and their first child, Jacques, was born April 7, 1859, and was followed by a second, Leo, some ten years later.

The father's sympathies were strongly French and thus it came about that the eager mind of Jacques absorbed French as well as German culture, all the more because he lived in a region where French influence made itself strongly felt. His father, hating Prussianism, looked longingly toward the democratic institutions of France and of the United States.

In 1873 the mother died and three years later the father followed her. Jacques, an orphan of 16, accepted a position in the bank of an uncle in Berlin. Shortly after, on the advice of an uncle, Professor Harry Bresslau, he entered the Askanische Gymnasium in Berlin. It was a purely classical school, with very little science, from which he graduated at the head of his class, with special mention for fluency in speaking Latin. At his departure his teachers gave him a copy of Zeller's "Philosophie der Griechen" with an inscription cautioning him not to become too liberal!

His teachers took it for granted that he would become a philosopher and with this in mind he entered the University of Berlin in 1880 and attended the lectures of the philosopher Paulsen. But he soon concluded that metaphysical philosophy could not give satisfactory answers to the two questions uppermost in his mind: Is there such a thing as free will? and, What are the instincts?

He seems to have conceived a distaste for metaphysics at this time and in his subsequent career the only philosopher who influenced him appears to have been Mach.

The second semester of this academic year was spent at the University of Munich: then, hoping to gain some light on the question of the will, he went to Strassburg, entering the laboratory of Goltz who was studying localization in the brain and endeavoring to refute the theories of Munk and Hitzig. Here he remained five years and on the advice of Goltz took a medical degree in 1884 and the Staatsexamen in 1885. He then spent a year with Zuntz in Berlin where he continued his work on brain physiology.

The results of his work were presented in a thesis entitled "Die Sehstörungen nach Verletzung der Grosshirnrinde" (1, 2).[1] Munk and Hitzig promptly denounced the paper and its author in no uncertain terms. There was nothing personal in this since it was merely a natural consequence of the rivalry between opposing schools at a time when bitter polemics were only too common in Germany. Nevertheless it was a severe disappointment after five years of hard labor and it was a comfort to receive a letter from William James congratulating him upon his maiden publication: for this friendly act Loeb did not cease to be grateful and throughout his life he always seemed to be on the lookout to perform similar acts of kindness for young scientists.

He was now fairly launched on the scientific career which he pursued with extraordinary success and which revealed mental powers of the highest order. His restless mind must continually find new ideas and new enthusiasms as an outlet for its energies. He had a passionate love of truth and what appeared to him to be true had to be so expressed that all could feel the inspiration and see the beauty of what

[1] The numbers refer to the numbers in the bibliography which appears in this number of the Journal.

he saw. He sought in vain for the solution of his problems in the current philosophies of the day: then came his conversion to mechanism. Faith in mechanism became the religion to which he devoted his life, and it was a religion which his love of truth forced him to test by the most rigorous scientific standards.

The ardor with which he labored cannot be understood unless we realize that to him a scientific career meant the consecration of his life to the cause of humanity. He sometimes explained his devotion to work by the whimsical remark that it was his pleasure, a kind of sport, an adventure in the unravelling of mysteries. An excellent half-truth, all very well for those who could not see beneath the surface! But at bottom was not only the drive of an active and powerful mind but a consuming desire to help suffering humanity to which his heart went out in passionate pity. He seemed continually to carry some part of the load of human sorrow. Even in his happiest moments this feeling never left him and in the latter years of his life he suffered intensely as he saw the hatred let loose by the war.

He believed that the ills of mankind spring wholly from ignorance and superstition and are curable only by the search for truth. To quote his own words: "What progress humanity has made, not only in physical welfare but also in the conquest of superstition and hatred, and in the formation of a correct view of life, it owes directly or indirectly to mechanistic science" (263). He believed that science will lead to a philosophy free from mysticism by which the human spirit may achieve a lasting harmony with itself and its surroundings: such a goal can be reached only by research, which will no doubt show less natural perversity than natural goodness and prove altruism to be an innate property of human nature, just as the tropisms and instincts are inherent in lower organisms. To establish such a conception seemed worthy of his utmost effort.

If we realize that the great driving force of his life lay not only in a powerful intellectual urge, but also in a profound emotion we may better understand his zeal and why he attacked most eagerly the subjects where mysticism was most strongly entrenched. No matter how great the difficulty he seemed determined, as far as possible, to reduce everything to mechanism and his courage was often justified by startling success. When unable to solve the problem

his keen hypotheses, often startling in their audacity and beauty, and attractive for their simplicity and clarity, aroused and stimulated his readers. Often his dreams were as inspiring as his actual discoveries.

Not long after leaving Zuntz the direction of his future work began to show itself. In the fall of 1886 he became assistant to Fick, professor of physiology at Würzburg. Here the famous botanist Sachs became his friend, even going so far as to invite him to go on his walks, a condescension most unusual from an ordinarius to an assistant. And under the influence of Sachs his program commenced to assume more definite form. He had begun with the problem of the freedom of the will and his formulation of it was characteristic: if the will be free it cannot be controlled; this question must be tested experimentally. At that time it was customary to attribute volition to lower animals and it was natural to attack the problem there. The idea that behavior might be controlled by operations on the brain led to his experiments with Goltz. But these did not seem promising, and for a time he was uncertain.

It was the privilege of Sachs to lead him in the right direction, for Loeb saw that if he could control animals as Sachs controlled plants the problem of the will could be attacked scientifically. He lost no time in setting to work: the results exceeded his fondest hopes and henceforth the way was plain. He went forward so rapidly that in two years he had published his first paper on the theory of animal tropisms that was to bring him fame.

In the fall of 1888 he returned to Strassburg as assistant to Goltz and while here he did some work in collaboration with v. Korányi of Budapest (14). The winter of 1889–90 he spent in Naples carrying on experiments on heteromorphosis and the depth migrations of animals (in the latter work collaborating with Groom (16)): and it was here that he became interested in America through his contact with Henry B. Ward and W. W. Norman.

In the spring of 1890, at the home of Professor Justus Gaule (professor of physiology in Zürich and a former assistant of Goltz), he met a young American, Miss Anne Leonard, who had just received her doctorate in philology at the University of Zürich. The acquaintance resulted in an engagement and they were married in October of the

same year. After the marriage, which took place in America, they returned to Naples for the winter where he devoted himself to experiments on heteromorphosis since he was convinced that not only the "will" of the animal but also the form and function of its organs and its course of development might be controlled by the experimenter, an idea quite contrary to concepts then prevailing.

At this time he was undecided whether he should continue to live frugally on his patrimony and devote himself wholly to research or accept an academic chair, which he dreaded because of its interference with his investigations. But he deemed that his new responsibilities made it imperative to find a position. Feeling more and more irritation at the military and political conditions in Germany, and having, like his father, a hatred of militarism, his thoughts turned toward America. But there was no position in sight. At last he had an inspiration: he would earn his living as an oculist, devoting part of his time to practice and the rest to research. He began to frequent the clinic of his friend Dr. Fick, in Zürich, but after six weeks gave up in despair, saying "I cannot live unless I continue my scientific work. These problems haunt me night and day and I must go on or perish." While in this state of mind he received an offer of a position at Bryn Mawr College from Miss Thomas (then dean of Bryn Mawr) which was accepted with enthusiasm. He arrived in Bryn Mawr in November, 1891, to assume his new duties, having been delayed owing to the arrival of his first-born child, Leonard.

He was happy to be in America and he enjoyed Bryn Mawr. He had a few graduate students, among whom was Miss Ida H. Hyde. But the facilities for his work were insufficient and in January, 1892, when Dr. Whitman asked him to join his staff at the new University of Chicago, he accepted. At the same time he agreed to give the course in physiology at Woods Hole during the following summer.

At Woods Hole he was in his element. He enjoyed giving the course: he was able to work without hindrance and he met a group of men who shared his ideals and enthusiasm. He spent most of his summers in Woods Hole during the remainder of his life, except for the years spent at the University of California.

On reaching Chicago in the autumn he found things in a state of chaos. The World's Fair was in preparation and only one university

building was completed. An apartment house had been leased for a year to harbor the scientific departments of the university (one department to a floor). When the first quarter opened there was not a piece of apparatus in the building. In this, as in so many other trying circumstances, Loeb's sense of humor came to his aid: it was one of his outstanding qualities and it is a great pity that this sketch cannot, from its very nature, dwell upon it. But those who seek to understand his character should not underestimate this quality which was a wonderful help in a long and difficult struggle, made doubly trying by his supersensitive nature.

The following ten years in Chicago were busy and happy ones during which he became a naturalized citizen and definitely took root in the United States. An important circumstance linking him more firmly to his new environment was the birth of two children, Robert F. and Anne, which had the greater significance because of his intense devotion to domestic life. Indeed his every moment, apart from his laboratory, was spent with his family.

After a short time the department of physiology was separated from that of biology and Loeb was placed at its head; David J. Lingle and A. P. Mathews were associated with him in the department. A physiological laboratory was dedicated in 1897. Among those who worked with him during this period (either at Chicago or Woods Hole) were C. R. Bardeen, Elizabeth E. Bickford, O. H. Brown, S. P. Budgett, Elizabeth Cooke, Martin H. Fischer, W. E. Garrey, W. J. Gies, A. W. Greeley, Irving Hardesty, W. H. Lewis, R. S. Lillie, E. P. Lyon, S. S. Maxwell, Anne Moore, C. H. Neilson, W. W. Norman, R. Burton Opitz, W. H. Packard, J. van Duyne, R. W. Webster, Jeanette C. Welch, and W. D. Zoethout.

His work was at first largely concerned with tropisms and heteromorphosis. He found that these studies involved recent discoveries in chemistry and physics. He became deeply interested in the theory of Arrhenius and thus came to write the famous series of papers on the physiological effects of ions. A direct outgrowth of this was his discovery of artificial parthenogenesis and antagonistic salt action in 1899.

The winter of 1898–99 was spent in California at Pacific Grove, where he had expected to work on marine material but since he was unable to carry out this plan he devoted his time to writing. The

outcome was the "Comparative Physiology of the Brain and Comparative Psychology" (62) written in German and translated by Mrs. Loeb. This was not an isolated instance of her aid for she constantly cooperated with him in literary work.

Loeb was greatly attracted by the genial climate and the possibility of working on marine material all the year around, and when a call to the University of California came in 1902 he accepted. A laboratory was built for him at Pacific Grove not very far from the site of the Jacques Loeb Laboratory to be erected by Stanford University. The University of California Publications in Physiology began in 1903; in October of the same year the physiological laboratory at Berkeley was dedicated, the principal address being delivered by Wilhelm Ostwald. In the following year Arrhenius and de Vries spent some time at the University of California to the great delight of Loeb who had become deeply interested in their work: this acquaintance ripened into a firm friendship. This is equally true of the later visits of Boltzmann and Rutherford.

Among those who worked with him at this time were F. W. Bancroft, G. Bullot, T. C. Burnett, G. C. Elder, M. H. Fischer, A. L. Hagedoorn, W. O. Redman King, E. v. Knaffl-Lenz, H. Kupelwieser, C. B. Lipman, J. B. MacCallum, S. S. Maxwell, A. R. Moore, Wolfgang Ostwald, T. B. Robertson, C. G. Rogers, Charles D. Snyder, R. Wulzen, and H. Wasteneys.

In accepting the call to California Loeb had not realized how much he would be cut off from contact with his fellow scientists. He was naturally so averse to travel that he made no attempt to attend meetings of his colleagues in the East (and it was surprising that in 1909 he attended the Darwin Centenary in Cambridge, England, went to the VIth International Congress of Psychology in Geneva, the 350th Anniversary Celebration of the University of Geneva, the 500th Anniversary Celebration of the University of Leipsic, and to the XVIth International Congress of Medicine in Budapest, and in 1911 attended the first Monist Congress in Hamburg). This isolation had much to do with his consideration of offers from Europe (especially from Budapest) and his final acceptance of a call to The Rockefeller Institute for Medical Research in 1910. He desired to be able to devote himself entirely to research and he was deeply inter-

ested in the idea of carrying on work in general physiology in connection with medicine. He thought that in this way those engaged in medical research might more easily see to what extent advance in the art of healing depends on our knowledge of the nature of the cell and how medical progress may be quickened by such fundamental principles as general physiology can supply. (See in this connection the letter reproduced on pages xvii–xix.)

He found the atmosphere of the Institute so congenial and stimulating that his activity in research became greater than ever. He delighted in meeting other workers at the noon hour when all the staff lunched together and he inspired the younger men as few could do.

In 1918 he founded the Journal of General Physiology (in collaboration with the writer) and a series of Monographs on Experimental Biology (in collaboration with T. H. Morgan and the writer), both of which met obvious needs.

Among those who worked in his laboratory (either at the Institute or at Woods Hole) were F. W. Bancroft, M. G. Banus, R. H. Beutner, McKeen Cattell, K. G. Dernby, W. F. Ewald, D. I. Hitchcock, K. v. Körösy, M. Kunitz, R. F. Loeb, Mrs. A. R. Moore, J. H. Northrop, H. Wasteneys, and N. Wuest. It should be added that throughout his connection with the Institute his labors were lightened by the efficiency and devotion of his secretary, Miss Nina Kobelt.

His previous studies were continued for a time and later there were new developments, such as his investigations on bioelectrical phenomena and on quantitative aspects of regeneration. He also took up anew the properties of proteins. It was a subject that had long attracted him: he had made a beginning years before but there seemed then to be no guiding principles sufficiently well established to make it possible to proceed with assurance. Nevertheless the problem was constantly in his mind and at length he discovered a way to attack it. In his earlier researches the dissociation theory of Arrhenius had furnished a clue and in the later work he found a guide in the Donnan principle. By applying this he was able to give quantitative explanations of some of the most important properties of colloids and to reduce them to simple mathematical laws.

In the midst of this important work he was persuaded to go to Bermuda for a brief holiday. A few days later he was stricken with angina pectoris, and after a short illness his death occurred, on Febru-

My dear Flexner!

I do not know whether or not you received my answer to your telegram, in which I said that I could more conveniently come now than later. This term was my period of lecturing in Berkeley and I am hungry to go back to my experiments in Pacific Grove. I shall start there today but shall be ready to start for New York at the end of next week, as in this time I think I can get a piece of work under way and make a ~~start~~ beginning in my experi-

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I wish to tell you how much I
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latter on a physico-chemical
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mental biology — the experimental
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I do not think that the medical
Schools in this country are ready
for the new departure; if the
experimental Biology in the
Zoological departments will be
one sided and remain so. The
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ary 11, 1924. It had always been his desire to work up to the last moment and to die in one of the places whose natural beauty appealed to his imagination. It seemed therefore in accordance with his wish that the end should come during a visit to Bermuda in the midst of the most active investigations of his life.

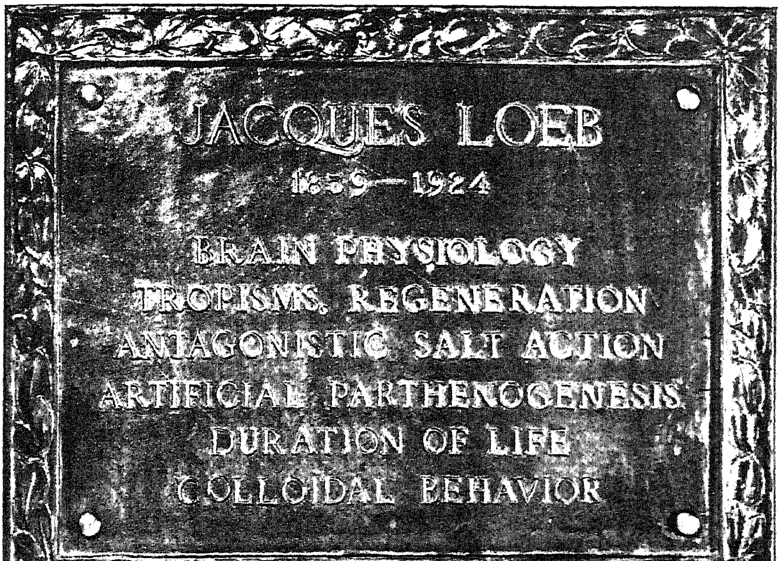
His ashes were brought to Woods Hole for interment. A memorial tablet was placed in the Marine Biological Laboratory and in The Rockefeller Institute for Medical Research. It is bordered by the leaves of *Bryophyllum*, which had served for his experiments on regeneration but which he had not known in its wild state until in Bermuda he had been delighted to see it everywhere blooming profusely.

Enshrined within this border are the chief subjects to which he devoted himself during a life time of unremitting labor. All of them represent fundamental problems of biological research. Though at first sight they may seem to present no obvious continuity it would be a great mistake to suppose that it is absent. As with all great investigators, each new question arose naturally out of the preceding. There was no running after strange gods or foreign problems. The task in hand demanded all his power of attention and it rewarded the seeker by continually unfolding new and promising leads to the very last. The end was not discernable at the start: nor did he dream when beginning with the freedom of the will that he would end by studying colloidal systems. Yet it was a transition as natural as the progress of Pasteur from crystals to microbes.

II.

Loeb's work was too diversified and extensive to permit a complete account in the limits here prescribed. The most that can be attempted is a general sketch of the evolution of his ideas, omitting all details save those which give definiteness to the picture.

To understand the development of his thought we must go back again to the start. He began with the problem of the freedom of the will and he felt that in experiment lay the only chance of progress. He turned, naturally enough, to the idea that behavior might be controlled by operations on the brain: for this reason he went to study with Goltz. Here he became acquainted with the experiments on



Marine Biological Laboratory, Woods Hole, Mass., and The Rockefeller Institute for Medical Research, New York, N.Y.

dogs which had led Munk to think that the act of vision involves a projection from the retina to a certain region of the cerebral cortex and that extirpation of certain parts of this region produces blindness in corresponding parts of the retina. Loeb carefully repeated these experiments but was unable to confirm Munk.

Many years afterward Henschen concluded from observations on human pathology that such a projection exists but not in the part of the cortex where Munk had located it and this idea was confirmed by Minkowski's experiments on dogs. Loeb then took up the discussion from an entirely new angle. He called attention to the work of investigators who had found that in the coloration of their skins certain fish reproduce a pattern, such as a checker board, forming the bottom of the aquarium. Extirpation of the eyes or of the optic ganglia in the brain or cutting the sympathetic nerve fibres which go to the pigmented cells of the skin prevents this phenomenon. Hence the path is known and Loeb suggested that what travels along this path may be an "image" in the sense that for each dark or bright point of the object there is a corresponding state of excitation first in the retina and subsequently in the optic nerves and in their terminal ganglia in the brain.

This illustrates what often happened in his work. Dropping a problem which did not seem to be leading anywhere he would nevertheless keep it always in the back of his mind so that if new facts turned up he could at once turn them to good use.

Seeing the necessity for quantitative methods in dealing with the physiology of the brain he devised a method of measuring the effects of attention and mental activity by recording the pressure exerted by the hand upon a dynamometer while the subject was engaged in reading or ciphering (5). It was found that these activities had a decided effect on the pressure imparted to the dynamometer.[2] This idea proved to be useful and suggestive.

Later Loeb returned repeatedly to the physiology of the brain and in his book on the subject (62) made useful suggestions such as those found in his discussion of the sequence of reflexes proceeding from one segmental reflex to another which he called "chain reflexes."

His early work on the brain had failed to open the experimental

[2] *Cf.* also Welch, J. C., *Am. J. Physiol.*, 1898, i, 283.

approach that he had hoped for. But fortunately he soon afterward came under the influence of Sachs who had clearly shown that plants in their responses to light and certain other stimuli behave as simple machines. Not only the brilliant experiments of Sachs but his remarkable personality, his creative imagination, and broad philosophic viewpoint inspired Loeb, who was seized with a desire to test upon animals the illuminating conceptions that Sachs had formulated in studying plants.

Loeb's method of procedure is illustrated by his experiments on the caterpillars of *Porthesia* which issue from their winter nests and climb to the tips of the branches of trees where they find the opening buds which serve them as food. It was supposed that they found the right situation, in some cases before the food was actually ready, by a marvellous instinct. To explain the origin and the heredity of such an instinct might seem to require very complicated hypotheses. But Loeb brushed all this aside by a few simple experiments showing that these animals are slaves of the light. They climb upward toward the light until they reach the tips of the branches and there they remain. They act like photochemical machines to such an extent that if food is placed behind them when they are starving they are unable to turn their heads away from the light to take nourishment. It seemed possible that this effect might be produced by a photosensitive substance reacting more strongly on the illuminated side and hence (through the medium of the nervous system) affecting unequally the symmetrical muscles on the two sides so as to turn the head toward the light. To explain the heredity of such an "instinct" we need only suppose that the parent transmits to the offspring the ability to produce the photosensitive substance under the proper conditions.

One must therefore cease to speak of the will of this animal and regard it as a matter of mechanism, completely under the control of the experimenter. "The desire of the moth for the star" began to seem less mysterious.

Thus at the very outset he came to the conclusion that certain instincts may be resolved into tropisms and it soon became evident that no hard and fast line could be drawn between instinct and intelligence. In later work he developed these ideas. Finding that the

addition of carbonic acid to water may produce in an aquatic animal, ordinarily indifferent to the light, a reaction drawing it irresistibly toward a source of illumination, he raised the question whether this may help us to put certain psychological problems upon a physico-chemical basis. If behavior may be changed by the addition of an acid why not by the secretions of a gland? Might not this idea be applied to attraction between the sexes, which may involve a change from a selfish to an altruistic attitude? And why limit the consideration to glandular products? Since Pawlow and his pupils have produced a salivary secretion in dogs by means of optical or auditory signals it no longer appears strange that what we call an idea should bring about chemical changes in the body.

It is evident that these considerations may throw some light on the nature of ethics. Loeb put the matter as follows (214, page 31):

"If our existence is based on the play of blind forces and only a matter of chance; if we ourselves are only chemical mechanisms—how can there be an ethics for us? The answer is, that our instincts are the root of our ethics and that the instincts are just as hereditary as is the form of our body. We eat, drink, and reproduce not because mankind has reached an agreement that this is desirable, but because, machine-like, we are compelled to do so. We are active, because we are compelled to be so by processes in our central nervous system; and as long as human beings are not economic slaves the instinct of successful work or of workmanship determines the direction of their action. The mother loves and cares for her children, not because metaphysicians had the idea that this was desirable, but because the instinct of taking care of the young is inherited just as distinctly as the morphological characters of the female body. We seek and enjoy the fellowship of human beings because hereditary conditions compel us to do so. We struggle for justice and truth since we are instinctively compelled to see our fellow beings happy. Economic, social, and political conditions or ignorance and superstition may warp and inhibit the inherited instincts and thus create a civilization with a faulty or low development of ethics. Individual mutants may arise in which one or the other desirable instinct is lost, just as individual mutants without pigment may arise in animals; and the offspring of such mutants may, if numerous enough, lower the ethical status of a community. Not only is the mechanistic conception of life compatible with ethics: it seems the only conception of life which can lead to an understanding of the source of ethics."

He therefore regarded the study of tropisms as of fundamental importance not only for biology but likewise for psychology and for philosophy and he endeavored to place it upon a sound scientific basis.

He tried to find quantitative relations and he was able to show in some cases that animals obey the Bunsen-Roscoe law which states that equal amounts of energy in the form of light produce equal results (*i.e.* that for equal effects intensity multiplied by time of exposure equals a constant) as had already been shown for plants by Blaauw.

The tropism theory would lead us to expect that when light comes from two different directions an animal will place itself so that the eyes will be equally illuminated on both sides. If the relative intensity of the lights be changed the animal should change its position accordingly. If in addition the animal obeys the Bunsen-Roscoe law varying the time of exposure to the light should have the same effect as a proportionate change in the intensity. Ewald, working in Loeb's laboratory, found that the eye of *Daphnia* takes up a position in accordance with this law. Loeb then showed in collaboration with Ewald (240) and later with Wasteneys (291) that the heliotropic curvature of the stems of the polyp *Eudendrium* obeys this law. In collaboration with Northrop (300) he showed that the larvæ of the barnacle when exposed to two sources of light move at an angle which agrees with this law: they also showed that when the horseshoe crab is tethered by a string attached to its tail and allowed to orient itself between two sources of light the position it assumes is in accordance with expectation (389). These results together with those of other observers served to establish the principle on a firm basis.

As the result of Loeb's work the motions of animals came to be explained more and more on the basis of tropisms rather than of single reflexes: few movements exemplify simple reflexes and in many cases they represent groups of reflexes which are better described as tropisms.

The study of tropisms led him to question some current notions regarding the function of the central nervous system. The flight of the moth into the flame, which had been regarded as a typical reflex, he explained as a simple tropism like the turning of a plant to the light. In the case of the plant the mechanism consists of an apparatus for receiving the stimulus and for transmitting it to the place where the motion takes place. He therefore asks, Why is it necessary to assume anything else in this animal: why postulate that the central nervous system does anything more than transmit the stimulus? And why

not explain other reflexes on the same basis? This would indicate that the problem of coordinated movements needs a fresh attack and that the cause of coordination may, in some cases at least, be found outside the central nervous system.

It was a natural thing for him to pass on from the study of reflexes and tropisms to attack the problem of consciousness by seeking to resolve it into the simpler elements which compose it. He defined consciousness as the phenomena determined by associative memory the presence of which can be experimentally determined by ascertaining whether the animal is capable of learning: where this is lacking consciousness cannot exist. The fundamental problem of psychology is the mechanism of associative memory and the manner in which stimuli are transmitted; the method of attack is to try to discover what properties of colloids make such phenomena possible. For the solution of these problems we must use the methods of physical chemistry, particularly as employed in the study of protoplasm.

Many of these views are summarized in his "Comparative Physiology of the Brain and Comparative Psychology" (62) which had a strong influence, at a time when it was much needed, in replacing anthropomorphic speculation by sound experiment.

It may be added that although his attention was chiefly devoted to heliotropism where he could work quantitatively, he fully realized the importance of the other tropisms on which he made so many important observations. He pointed out very clearly the fundamental significance of tropisms in the struggle for existence, their importance in relation to adaptation, and their rôle in developmental mechanics. His writings gave an enormous impetus to the experimental study of animal behavior and encouraged the expectation that it might be brought under the control of the experimenter and his suggestions influenced both psychology and philosophy.

For him nothing was more natural than to go further and inquire: If we can control the behavior of the animal why not seek to determine also its form and development? This led to his experiments in the field which he called physiological morphology. He found it possible to control regeneration so that, for example, certain hydroids can be made to produce "roots" in place of "stems," just as botanists had previously found for plants. This he called heteromorphosis.

He accepted the explanation given by the botanists (and especially by Sachs) that the organs are determined by "organ-forming materials" so that where these materials collect the appropriate organs will be formed.

The impression made by these studies is well rendered by Herbst (whose opinion derives especial weight from his critical scientific attitude).

"Wirkten sie doch wie ein heller Sonnenstrahl, der plötzlich in das Dunkel der Morphologie fiel, die damals ganz im Banne phylogenetischer Forschung stand, welche wegen ihrer nicht zu beseitigenden Unsicherheit, ja mitunter Willkür, uns jüngere Forscher nicht mehr befriedigen konnte. Hier aber schienen einem Tatsachen gegeben zu sein, die in einem die Hoffnung erweckten, dermaleinst auch das tierische Gestaltungsgeschehen kontrollieren zu können. Freilich um die Entwicklung des Organismus aus dem Ei handelte es sich in diesen Arbeiten nicht, sondern nur um die Regeneration verlorengegangener Teile und um ähnliche Erscheinungen. Die Wirkung dieser Schriften war so gross, dass man sie nur mit derjenigen der Arbeiten von Trembley, Bonnet und Spallanzani auf Forscher und Laien der zweiten Hälfte des 18. Jahrhunderts vergleichen kann, denn wie damals die erste Hochflut in der Erforschung der Regenerationserscheinungen einsetzte, so wälzte sich nach dem Erscheinen der Beiträge Loebs die zweite heran, befruchtend und reichen Ertrag erbringend für die biologische Wissenschaft."[3]

He later produced such monstrosities as Siamese twins, triplets, or quadruplets in the egg of the sea urchin by diluting the sea water and causing the egg to burst and extrude one or more rounded masses of protoplasm. On replacing the egg in ordinary sea water each extruded portion gave rise to an embryo, as did also the main body of the egg to which it was attached, the attachment persisting as the embryos developed.

By such experiments he hoped to analyze the forces which control development, believing that the biologist should aim at as complete control of living matter as the physicist and chemist have over their material, and that the best hope of success lay in applying their methods to biology. He made brilliant use of this conception. He became especially interested in the dissociation theory and as one of the first results he published the well known series of papers on the physiological effects of ions. He thought that the specific effects of

[3] Herbst, C., *Die Naturwissenschaften*, 1924, xii, 400.

salts on the organism might be due to the combination of ions with substances in the protoplasm whose properties might thereby be altered. He found an analogy in the case of soaps where potassium makes a soft soap, sodium a harder one, calcium one that is still harder, and so on (63).

To test these ideas he exposed organisms to salts in varying concentrations. Fertilized eggs placed in sea water whose osmotic pressure had been increased by the addition of sodium chloride could not segment but if replaced in ordinary sea water after two hours they passed rapidly into a many-celled stage. His explanation was that in the more concentrated solution the nucleus divides but the cytoplasm is unable to do so; on replacing the eggs in ordinary sea water the division of the cytoplasm follows at once. Four years later Norman repeated this work, adding magnesium chloride to the sea water. Still later Morgan made similar experiments on unfertilized eggs and found on replacing them in ordinary sea water that they began to segment but this soon stopped and no larvæ were formed. About the same time Mead observed that the addition of a little potassium chloride to the sea water caused the unfertilized eggs of the marine worm *Chætopterus* to expel their polar bodies.[4]

Loeb found in 1899 (68, 69) that unfertilized eggs of the sea urchin which had remained for two hours in a mixture of equal volumes of sea water and two and a half molar magnesium chloride would develop into plutei when replaced in ordinary sea water. The announcement of this fact was received by his scientific colleagues with a degree of incredulity which bordered almost on indignation and there was a general feeling that his results must be due to contamination by sperm, which are widely dispersed throughout the sea water during the spawn-

[4] Prior to all of these observations was that of O. and R. Hertwig (1887) that eggs treated with strychnine occasionally segment a few times. Still earlier Greeff (1876) had observed that parthenogenesis sometimes occurs in the starfish *Asteracanthion* (the development did not proceed beyond the blastula stage) and O. Hertwig (1890) had confirmed this for *Asterias* and *Astropecten* but neither of these authors had determined the conditions under which this rare phenomenon took place. It was also known that eggs of arthropods, echinoderms, and annelids might begin to segment after lying for some hours in sea water. There also exist in the literature other reports of the beginning of cleavage under various conditions (122, pages 83 and 84, also 157).

ing season. There was, however, a difference in the appearance of eggs which were fertilized by sperm and those which were caused to develop by the treatment with magnesium chloride since in the latter the fertilization membrane is not as evident as in the former (indeed it was supposed for a long time that the latter had no membrane at all). Doubt presently disappeared and throughout the civilized world went a stir such as a scientific announcement seldom makes.

It was soon found that the action of magnesium chloride consisted merely in raising the osmotic pressure and that equally good results could be obtained by the addition of other neutral salts or even of sugar, as well as by the use of sea water concentrated by evaporation. This was therefore known as the osmotic method of artificial parthenogenesis.

Loeb stated that the importance of this discovery consisted in transferring the problem of fertilization from the domain of morphology to that of physical chemistry and he undertook to discover what physical and chemical changes cause the egg to develop. He first tried to imitate the formation of the typical fertilization membrane which is produced by the entrance of the sperm. He succeeded in this by exposing the eggs to certain fatty acids and then replacing them in sea water, but the development was not normal unless this treatment was followed by exposure to sea water of increased osmotic pressure or to sea water deprived of oxygen or containing a little potassium cyanide. In this case the plutei often appeared perfectly normal. Later Delage succeeded in carrying larvæ produced by artificial parthenogenesis to the stage of sexual maturity. It may be added that Loeb, using the method of Guyer and of Bataillon, later produced parthenogenetic frogs and raised them to sexual maturity (277, 354).

It is of interest to note that the sea urchins raised by Delage were males. The frogs raised by Loeb were of both sexes: the chromosome number was regarded by Goldschmidt as diploid and this was later confirmed by Parmenter.[5]

Two questions presented themselves, What are the physical and chemical changes which produce the fertilization membrane, and,

[5] Parmenter, C. L., *J. Gen. Physiol.*, 1925–28, viii, 1.

Why is the after-treatment necessary? To answer the first he sought to discover whether other means could cause the formation of the typical membrane. It was produced by certain cytolytic agents, particularly those which markedly affect surface tension, such as saponin, bile salts, and soap. It could also be produced by lipoid solvents, such as benzene and toluene (as Herbst and Hertwig had already observed), by alcohols and ethers, by certain bases, by ultraviolet light, and by other means. These agents are destructive and kill the egg unless it be removed in time and given an appropriate after-treatment.

Loeb concluded that all of these agents act on a substance, probably a lipoid, at the surface of the protoplasm causing certain colloids to swell and thereby lift up a delicate membrane from the surface (the question whether this membrane is preformed or is produced during the treatment is not essential). This could be brought about, for example, if the protoplasm at the surface consisted of an emulsion, the inner phase consisting of particles surrounded by a film of lipoid which might be removed by solution or precipitation or even by mechanical agitation so as to bring the particles into direct contact with the outer phase and cause them to swell and to lift up the fertilization membrane.

The question arose, How can an alteration of the surface of the sea urchin egg cause development? Perhaps by its effect on oxidation: Warburg had stated that oxidations occur chiefly at the surface, hence a change in the condition of the catalysts at the surface or an increase of permeability might increase oxidation.

When the membrane is formed in artificial parthenogenesis of the sea urchin there is a great increase in oxidation (as Warburg found) and the egg quickly dies if there is no additional treatment. But if oxidation is suppressed for a time (by depriving the eggs of oxygen or by adding a trace of potassium cyanide to the sea water) they live and can afterward develop normally. Temporary suppression of oxidation is evidently not the sole factor involved, since increased osmotic pressure is even more effective and certain narcotics act in much the same way without diminishing oxidation. All of these agents stop development for a time and this would seem to be the essential thing: during this period the egg has a chance to recover

from the effects of the treatment which produces the membrane and if the suppression does not last too long normal segmentation occurs when the egg is replaced in ordinary sea water.

His general conclusion was that the sperm brings to the egg two substances, one of which acts on the surface of the protoplasm in such a way as to form a fertilization membrane, the other factor having a corrective action which prevents any harmful results of the processes immediately following membrane formation.

Evidence in favor of this idea was obtained on placing unfertilized eggs of certain species of sea urchin in hyperalkaline sea water and adding starfish sperm. The results seemed to indicate that the sperm bears at its surface a substance which can cause membrane formation by mere contact with the egg but that the substance bearing the corrective factor lies deeper in the sperm and produces no effect unless the sperm actually penetrates the egg. At any rate many cases were found in which the sperm produced membrane formation but the eggs did not develop unless treated with hypertonic sea water and it was assumed that in these cases the sperm did not penetrate but merely induced membrane formation by coming in contact with the surface of the egg and that the membrane thus formed prevented the sperm from penetrating. In other cases where the egg went on developing it was assumed that the sperm had penetrated.

With some species of sea urchins it was possible to produce membrane formation with an aqueous extract of starfish sperm which had been killed by heating to 60°C. Such eggs behave like those treated with a fatty acid and it is necessary to give them the after-treatment with hypertonic sea water to make them develop normally, as was also the case if such eggs are subjected to the action of living sperm of the shark or the rooster which do not penetrate but only give to the egg the substance which causes membrane formation. If this substance were like the so called lysins of blood it would seem possible to produce membrane formation with the blood of various foreign species. This proved to be the case with the blood of ox, sheep, pig, and rabbit, and certain invertebrates. In some cases it was necessary to sensitize the eggs by preliminary treatment with strontium or barium. In all cases the eggs perish unless given the after-treatment.

Lysins of the sea urchin have no effect on eggs of the same species,

just as the lysins of sheep's blood cannot affect the corpuscles of sheep though they quickly destroy those of other animals. Is this because the lysins cannot penetrate cells of their own species or because antibodies protect the cells even if the lysins penetrate them? Loeb's answer was that if the egg of the sea urchin contained an antibody the sperm could not produce a membrane and it therefore seemed probable that the immunity of blood corpuscles to their own lysins may be due to the fact that the lysins cannot penetrate.

Other possible explanations have been suggested for many of the phenomena of artificial parthenogenesis, but those given here seemed to him on the whole the most probable. Later work brought to light new facts, as, for example, that the corrective treatment could precede as well as follow the treatment which produced the membrane, but these did not essentially change his viewpoint.

What has been said relates especially to the sea urchin. Other forms show divergencies: for example, in the starfish egg fertilization produces no increase in oxidation and other differences exist. But his main conceptions were developed from the experiments with sea urchin eggs and it has therefore seemed better to confine the account chiefly to these.

This brief outline of his method of analyzing the problem of fertilization says nothing of the many disappointments, the frequent failures, the long and tedious groping in the dark which preceded success. Nor does it touch on the wealth of new problems that came with each discovery. An example is seen in the experiments in which sea urchin eggs were treated with the sperm of the starfish. Under ordinary conditions no result is obtained but Loeb discovered that if the sea water were made slightly more alkaline fertilization took place and a normal development followed.

He found that fertilization could be brought about by the sperm of ophiurans, holothurians, or even of molluscs. But the employment of such foreign sperm did not affect the character of the larvæ which had the same appearance as if fertilization had been effected by sea urchin sperm of the same species.

Since development could be so easily started the question arose whether it could also be stopped and reversed at the will of the experimenter. The question of reversibility of development had first been

raised by Loeb in 1900 (75, 78) when he observed the transformation of a hydroid polyp into the less differentiated material of the stolon which can in turn give rise to a new polyp. Since that time a number of instances of reversibility have been described by other observers.

He found that the artificial parthenogenesis of the sea urchin egg induced by alkali was reversible. Eggs treated with the alkaline solution followed by a hypertonic solution would develop in sea water but if, after removal from the hypertonic solution, they were placed for a short time in sea water containing sodium cyanide or chloral hydrate they would not develop when replaced in sea water but acted as if no treatment had been given them (237, 239, 264). The initiation of development by butyric acid also proved to be reversible.

Another suggestion arising from the study of the developing egg concerns the mechanics of growth. During the first period of division the nuclear material of the egg increases in a manner which indicates that cytoplasmic materials are transformed into nuclear substance. Nuclear division may occur at fairly regular intervals and at each division the nuclear material is approximately doubled. It follows that the mass of nuclear material produced at each division is proportional to the mass already present which might mean that the reaction which produces nuclear material is catalyzed by some constituent of the nucleus so that the greater the amount of nuclear material already on hand the more rapid the rate of the reaction. This, as he pointed out, is the case with an autocatalytic reaction (125, 139, 168). This suggested to T. B. Robertson the possibility that the growth of the entire organism might agree with the curve of autocatalysis and an examination of the available data convinced him that this was the case. About the same time Wolfgang Ostwald reached the same conclusion.

The experiments on artificial parthenogenesis called his attention to the problem of natural death. This interested him profoundly, partly because of its bearing on ethical problems. Is death a necessary consequence of the process of growth and development, or is it something superimposed, capable of being postponed or eliminated? He expressed his views as follows:

"The writer showed in 1902 that the problem of fertilization is intimately connected with the problem of the prolongation of the life of the egg cell. The unfer-

tilized mature egg dies in a comparatively short time, which may vary from a few hours to a few weeks according to the species or the conditions under which the egg lives. The fertilized egg, however, lives indefinitely, inasmuch as it gives rise, not only to a new individual, but, theoretically at least, to an endless series of generations. The death of the unfertilized egg is possibly the only clear case of natural death of a cell, i.e., of death which is not caused by external injuries, and the act of fertilization is thus far the only known means by which the natural death of a cell can be prevented. The two problems, fertilization and prolongation of life, are thus interwoven, and the experiments on the mechanism of fertilization become at the same time studies on the problem of natural death and prolongation of the life of the egg cell." (157, English edition, page 1.)

He pointed out that while the fertilization of the egg by sperm of the same species prolongs the life of the egg indefinitely its span of life may be very brief if the sperm of certain other species is employed.

He found that the sensitiveness of the sea urchin to the effect of abnormal solutions increased as development proceeded so that when certain unfavorable solutions are improved by the addition of sea water the eggs die more quickly because they rapidly develop to a stage in which they are much more sensitive than before (245).

The discovery of artificial parthenogenesis made it possible to analyze the factors which prolong the life of the egg. The usual treatment of the sea urchin egg consists in first causing membrane formation in the unfertilized egg but eggs so treated die much more quickly than untreated eggs. It might therefore seem that the "corrective treatment" usually applied after membrane formation is responsible for prolonging the life of the egg. But when the corrective treatment is applied before membrane formation the eggs live no longer than untreated eggs: if the membrane formation is subsequently induced they live and develop. Hence it would appear as if both treatments are needed.

Membrane formation in the sea urchin egg appears to be followed by deleterious processes and only if the development of the egg be temporarily suppressed by the "corrective treatment" can it live. Under these circumstances we arrive at the paradoxical result that the life of the egg may be prolonged by the temporary application of potassium cyanide or by depriving it of oxygen or by subjecting it to the action of narcotics.

Another method of attacking the problem of death was by studying

temperature coefficients. He believed that this method had great importance for biology and workers in his laboratory had been pioneers in applying it to such life phenomena as the heart beat (Snyder, Robertson) and to nervous conduction (Maxwell, Snyder).

Experiments on the sea urchin egg (made at high temperatures) showed that lowering the temperature 1°C. doubled the length of life although it had been shown by the work of other investigators (with which his own agreed) that at lower temperatures it was necessary to raise the temperature 10°C. to double the speed of development. This might be regarded as an indication that development and death are not due to the same chemical processes for in that case no such difference in the effect of temperature would exist and this might explain the extraordinary richness of life in the colder parts of the ocean where the low temperature would have a much greater effect in prolonging the life of the developed organism than in retarding development.

But the question assumed a different aspect when experiments were made on vinegar flies (in collaboration with Northrop). They are so short-lived that the experiments can be carried on without raising the temperature to an abnormal level so that the normal duration of life is studied rather than the rate of killing by abnormally high temperature. They worked with vinegar flies free from microorganisms so that there could be no suspicion that death was brought about, as Metchnikoff had suggested, by toxic substances produced in the intestinal tract by the action of bacteria.

The experiments showed that the effect of temperature was practically the same on development and on length of life and this was interpreted to mean that the duration of life depends on the time required to complete a chemical reaction (or series of reactions). The nature of this reaction could not be defined but many of the cells of the body when removed from the influence of the rest can go on dividing indefinitely as shown by Leo Loeb, Harrison, and others, and especially by the experiments of Carrel. This is also true of cancer cells, as shown by Leo Loeb. Such cells are potentially immortal like the unicellular organism.

Closely connected with these subjects is that of oxidation which early occupied his attention and led him to suggest that the nucleus

is the center of oxidation in the cell. Later Warburg concluded that oxidation is largely confined to the surface of the sea urchin egg but the experiments of Loeb and Wasteneys did not confirm this view. They also made experiments on the effect of narcotics on the sea urchin egg and came to the conclusion that, contrary to the theory of Verworn, certain substances can produce narcosis with little or no diminution in the rate of oxidation.

Important as these problems were Loeb did not allow himself to be diverted from his basic program, out of which had sprung the experiments on artificial parthenogenesis. This program dealt with the fundamental properties of protoplasm as affected by ions. In order to ascertain the effects of individual ions it is desirable to employ an organism which can live either in distilled water or in fairly concentrated salt solutions. This is the case with the fish *Fundulus* whose eggs develop equally well in distilled water or sea water. Loeb was surprised to find that on adding to distilled water as much sodium chloride as is contained in sea water the eggs could not develop. in other words the sodium chloride is toxic and it was evident that the other salts found in sea water must somehow overcome this toxicity. The announcement of this fact was received with genuine astonishment.

He found that the addition of all sorts of salts with bivalent or trivalent cations in the right proportions could more or less completely remove the toxicity due to salts with monovalent cations. He spoke of this as antagonistic salt action and he called solutions such as sea water, in which the toxicity is suppressed by the admixture of salts in the proper proportions, a physiologically balanced solution. In order to have antagonistic salt action toxic salts must be present in sufficient concentration to produce injurious effects and these injurious effects must be overcome by other salts which have a protective action.

Botanists had long before found that plants (which can live for some time in distilled water) grow much better when certain salts are added. Very often such salts have only a nutritive function since there are no toxic effects to be overcome because the solutions are too dilute (just as *Fundulus* requires no addition of protective salts in a solution of sodium chloride having a concentration of 0.125 M or less). When

Herbst found that all the salts of sea water were needed to raise marine animals he worked from the same viewpoint. There was nothing to suggest that sodium chloride was toxic because his animals died very quickly in distilled water. But in the case of *Fundulus* eggs Loeb showed that the toxicity of sodium chloride could be largely overcome by adding salts without nutritive value; some, indeed, were very toxic when used alone, such as the salts of lead and zinc: it was evident that the action of such salts must be purely protective.

The striking fact that monovalent cations are antagonized by bivalent and still more by trivalent cations led Loeb to suggest that the sign and valence of the ion may in many cases be far more important than its chemical nature, as had already been found to be the case in certain experiments on colloids. This suggestion proved to be a highly stimulating one.

Ringer had found long before this that when the heart of a frog is perfused with a solution of sodium chloride the beats gradually diminish and ultimately cease: the addition of either calcium or potassium makes possible a resumption of activity but the beats are not normal unless both calcium and potassium are added in the proper proportions. Ringer concluded that there exists between calcium and potassium an antagonism analogous to that which exists between certain poisons of the heart, for example between atropine and muscarine: but for Ringer sodium chloride was an indifferent substance whereas Loeb regarded it as toxic. It may be added that Oscar Loew had shown that the toxicity of magnesium for certain plants largely disappears if sufficient calcium is added. But these workers arrived at no such far-reaching conclusions as Loeb. The experiments on *Fundulus* opened up a new point of view: had not this been the case they could not have created so much interest. In this connection we may quote the remarks of Höber:

"Loeb fand, dass das Ca nicht bloss durch die chemisch verwandten Mg, Sr und Ba ersetzt werden kann, sondern auch durch die Protoplasmagifte Ni, Mn, Zn, Pb, Cr u.a. Dies war ein so unerhörter Befund, dass im Hinblick darauf ein so ausgezeichneter Kenner der Salzwirkungen wie Overton damals den Satz schrieb: 'Dass die Calciumsalze durch Bariumsalze oder die Salze der zweiwertigen Schwermetalle in keiner Weise ersetzt werden können, müsste jedem toxikologisch gebildeten Physiologen von vornherein klar sein.' Heute haben wir

eine Reihe von Beweisen dafür, dass in der Tat—mehr oder weniger gut—die zwei- und dreifach positiv elektrisch geladenen Ionen einander vertreten können, und obwohl Loeb, wie gesagt, aus seiner Entdeckung mit weitreichendem Blick sofort die Konsequenz auf die Kolloidchemie zog, so hat diese doch erst in neuester Zeit, in unmittelbarer Anknüpfung an die physiologischen Vorbilder, besonders durch Studien von Freundlich, das richtige Nachbild schaffen können; es gibt anorganische Kolloidsysteme, die das physiologische Kolloidsystem recht getreu imitieren. Loebs Entdeckung war der wichtigste Anstoss, das Interesse an dem Studium der physiologischen Bedeutung der Salze neu zu beleben und zugleich durch rein theoretische Untersuchungen zu vertiefen, und wieviel das besagen will, das lehrt ein Blick in die physiologische, pharmakologische und klinische Literatur unserer Tage. Sie strotzt von Untersuchungen über Ionenwirkungen; um kleinsten Schwankungen in den Normalkonzentrationen der Ionen nachgehen zu können, wurden vorzügliche Mikromethoden ersonnen; die Wirksamkeit der normalerweise anwesenden Kationen, besonders der mehrwertigen Ca und Mg, wurde von den verschiedensten Seiten beleuchtet, ihr Verhältnis zu den Protoplasmakolloiden, insbesondere zum Eiweiss, und ihr Verhältnis zu den Ionen des Wassers vielseitig durchforscht, wobei auch wichtige klinische Interessen und das Interesse am Ausbau der Theorie ihrer Wirkungen gewichtig mitsprachen; die Erforschung der bioelektrischen Phänomene trat in ein neues Stadium ein. Bei diesem ganzen Neubau hat Loeb selber an den verschiedensten Stellen mitgewirkt."[6]

When an organism can live in distilled water the question of antagonism is perfectly clear, but when this is not the case there may be difficulty in distinguishing between the nutrient and the protective effects of salts. *Fundulus* in its early stages develops as well in distilled water as in sea water but this cannot continue indefinitely since, for example, calcium is necessary for the formation of bones. When *Fundulus* develops in sea water the function of calcium may be purely protective at the start; later it becomes nutritive also.

But notwithstanding the complications due to nutritive functions, the importance of the protective action of salts is clearly evident in such solutions as sea water. This is also true of the blood of mammals and in this connection Loeb experimented on muscles, finding for example that in the absence of calcium they undergo rhythmical contractions, and he suggested that this might account for tetany under certain conditions. This suggestion has since found practical application in medicine.

The important question arose, What is the mechanism of the pro-

[6] Höber, R., *Klin. Woch.*, 1924, iii, 511.

tective action of salts? Loeb found that as soon as the embryo escaped from the egg membrane the whole picture changed and it was no longer possible, for example, to diminish the toxicity of sodium chloride by the addition of salts of lead or of zinc. Nor did calcium alone suffice to remove toxicity since the addition of potassium was also necessary (282).

He therefore concluded that the membrane plays an important rôle and that in a balanced solution the salts probably acted on it (or perhaps on the micropyle, which is regarded as especially permeable) in such fashion as to make it less permeable than in a solution containing a single salt. Hence it would appear necessary that the salts should act simultaneously in protective action: this is not the case with nutrient action where the salts can be given in succession.

The recent work of Bodine[7] and of Armstrong[8] indicating that dissecting off the membrane makes no essential change in certain reactions of the embryo, appears to mean that the seat of action is in these cases at the surface of the embryo.

Loeb also found that when eggs are placed in sufficiently concentrated sea water they float for several days. In a solution of pure sodium chloride they quickly sink and since he regarded the egg as normally almost impermeable to water he believed that this result indicated that salt had entered. Addition of a small amount of calcium chloride to the solution of sodium chloride enabled them to float for days, indicating that it inhibited the entrance of salt.

But it is also possible to assume that in certain cases penetration occurs and that the antagonistic action takes place in the protoplasm, especially in those cases where acids are antagonized by salts and the experiments show that the acid is absorbed by the organism (270).

He also considered the possibility that certain salts penetrate more rapidly because they attach themselves to the surface so as to form a more concentrated layer which increases the concentration gradient. If some of the salt in this layer is displaced by another salt the entrance of the first salt will be somewhat inhibited (and its exit facilitated) producing an antagonistic effect (266). In this connection he made

[7] Bodine, J. H., *Proc. Nat. Acad. Sc.*, 1927, xiii, 698; *Biol. Bull.*, 1928, liv, 396.
[8] Armstrong, P. B., *J. Gen. Physiol.*, 1927–28, xi, 515.

some very striking experiments with the dye neutral red: *Fundulus* eggs stain more rapidly in distilled water than in solutions containing salt or acid and lose the dye more rapidly in solutions containing salt or acid (without dye) than in distilled water.

The question of permeability began to assume an increasing importance as a factor which controls all the activities of the cell, but it was evident that for satisfactory progress methods must be found of determining exactly how fast substances can penetrate. He tried to test the hypothesis of Overton that the surface of the cell is lipoid and allows only substances soluble in lipoid to enter the cell. This seemed improbable because water passes rapidly into the cell and the substances normally taken up by the cell are in general insoluble in lipoid but are soluble in water. It seemed to him more probable that the surface of the cell is a protein film, such as forms spontaneously on the surfaces of aqueous solutions of protein. At the same time he thought that lipoids are present in or close to the surface of the egg and that they play an important rôle in the formation of the fertilization membrane.

Since as a rule salts are almost or quite insoluble in lipoid they could not be expected to penetrate a lipoid film, unless very slowly. But Loeb found evidence for the penetration of salts: for example, after the heart has begun to beat in the embryo of *Fundulus* (while still enclosed in the egg membrane) it can be brought to a standstill by the penetration of potassium salts. It was found (266, 269, 286, 287, 288, 289) that the membrane was almost impermeable to potassium salts in very dilute solutions but that the addition of more potassium salt (or certain other salts) made it more permeable: he called this "the general salt effect." If too much salt was added it again became impermeable (antagonistic effect).

He pointed out the analogy to globulins which are insoluble in low concentrations of salts, become soluble when the concentration increases sufficiently, but again become insoluble when the concentration becomes too great. He was therefore inclined to think that the increase of permeability was due to the solubility of a constituent of the membrane which behaves like globulin. On this basis one might expect that the addition of a neutral salt would increase the diffusion of alkali into the egg (and augment its toxicity) but would have the

opposite effect on the diffusion of acid since analogous effects are observed on the solubility of globulins (303). The experiment showed that this expectation was justified.

Loeb found that to a certain extent the behavior of potassium in entering the cell is paralleled by that of acids (270). He observed that weak acids and bases appear to penetrate much more rapidly than strong ones, indicating that the protoplasm is not readily permeable to ions.

As part of his studies on the physiological effects of ions he desired to take up bioelectrical effects but his distrust of all but the simplest apparatus led him to postpone it until the advent of Beutner, whose training fitted him especially for the task. Together they studied the very interesting phenomenon of the "concentration effect," that is, the potential difference observed in leading off from two places in contact with different concentrations of the same salt. Employing mostly such plant tissues as apples and leaves of the India rubber tree they found that in dilute solutions they obtained the maximum values which were theoretically to be expected. The results indicated that the organism acts as a reversible electrode for all sorts of cations but the effects due to protoplasm are difficult to separate from those due to the dead cell wall.

Somewhat similar results had previously been obtained by MacDonald but their theoretical significance had not been understood and the work had been largely overlooked.

Loeb and Beutner endeavored to find non-living models which would act similarly and this undertaking (subsequently continued by Beutner) led to the discovery that many organic substances immiscible with water not only give the concentration effect but also act somewhat like living tissue when brought in contact with a series of different salts of the same concentration (chemical effect). Thus the way was opened up for the study of bioelectrical phenomena on a new basis.

As an illustration of his courage in attacking difficult problems we may consider his treatment of organization and adaptation. He was led to this problem by his experiments on the development of the egg. His general attitude may be stated in his own words:

"It is generally admitted that the individual physiological processes, such as digestion, metabolism, the production of heat or of electricity, are of a purely

physicochemical character; and it is also conceded that the functions of individual organs, such as the eye or the ear, are to be analysed from the viewpoint of the physicist. When, however, the biologist is confronted with the fact that in the organism the parts are so adapted to each other as to give rise to a harmonious whole; and that the organisms are endowed with structures and instincts calculated to prolong their life and perpetuate their race, doubts as to the adequacy of a purely physicochemical viewpoint in biology may arise. The difficulties besetting the biologist in this problem have been rather increased than diminished by the discovery of Mendelian heredity, according to which each character is transmitted independently of any other character. Since the number of Mendelian characters in each organism is large, the possibility must be faced that the organism is merely a mosaic of independent hereditary characters. If this be the case the question arises: What moulds these independent characters into a harmonious whole?

"The vitalist settles this question by assuming the existence of a pre-established design for each organism and of a guiding 'force' or 'principle' which directs the working out of this design. Such assumptions remove the problem of accounting for the harmonious character of the organism from the field of physics or chemistry. The theory of natural selection invokes neither design nor purpose, but it is incomplete since it disregards the physicochemical constitution of living matter about which little was known until recently." (290, pages v-vi.)

The question therefore is, What ensures the integrity of the organism? He suggested that the unity of the organism might be largely determined at the outset by the structure of the protoplasm. In some eggs a definite structure is indicated by regions differing in appearance: from each of these certain organs arise. In these cases the egg might be regarded as a rough model of the future embryo. The harmonious correlation of the parts of the embryo might therefore be determined by the arrangement of the parts of the egg.

The fact that the structure of the egg is important might possibly be related to the fact that the size of the egg cannot be artificially diminished beyond a certain point without interfering with development. He undertook experiments like those performed on infusoria by Nussbaum and, employing different methods, caused the egg of the sea urchin to break up into small fragments. He concluded that only those fragments develop into plutei which contain in addition to the nucleus a sufficient amount of certain constituents of the cytoplasm.

Loeb felt that those who thought it impossible to account for development on a physicochemical basis might have been misled by the

assumption that the cytoplasm of the egg is more homogeneous than is actually the case. He believed that proper recognition of the importance of the structure of the egg might change this point of view.

There are other things to consider, such as the mutual influence of the various parts, a factor which is capable in many cases of a mechanistic explanation. Thus he observed that in the yolk sac of *Fundulus* the pigment cells have at first no definite arrangement "but that they gradually are compelled to creep entirely on the blood vessels and form a sheath around them with the result that the yolk sac assumes a tiger-like marking." He regarded this as a tropistic reaction and believed that such reactions play an important part in development.

An analysis of the mechanics of development must include a study of regeneration. It had been assumed by some that when a missing part of the organism is replaced there must be a directive force which ensures that the regenerated part shall be just what is needed to complete the organism and enable it to perform its functions. Loeb found many cases where this is not so; for example, under some conditions a hydroid instead of regenerating a lost stolon produces a polyp "so that we have an animal terminating at both ends of its body in a head." Such cases of heteromorphosis are difficult to explain on the basis of a directive force which operates to supply the needs of the animal. They become more intelligible if we assume that the formation of organs is due to specific substances (as had been postulated by Sachs and others in the case of plants) and that where these substances accumulate the organ in question will be formed. This accumulation can be controlled to a certain extent by the experimenter. Loeb discussed this in connection with such cases as the development of legs in tadpoles. Young tadpoles have no legs but the mesenchyme cells from which the legs are to develop are present at an early stage. Ordinarily no growth occurs during a long period (from four months to a year or more) but Gudernatsch found that legs can be made to grow even in very young specimens by feeding them the thyroid glands of various animals. The mechanism of this process is not clear but Loeb suggested (257) that the stimulation of the growth of body cells might be analogous to the process by which the egg is caused to develop, *i.e.* by changes at the surface of the cell.

Another way in which one part can influence another is illustrated in

plants: it seemed clear from the work of previous experimenters, as well as from his own, that one part can inhibit another by diverting the flow of formative material. Thus a bud at the top of the stem takes the material away from one lower down but if the terminal bud be removed the other begins to develop.

These facts made him feel that a mechanistic approach to the problem was possible. He went on to examine the equally important question of adaptation. He showed that many characteristics of the organism which are regarded as adaptive may be explained on a mechanistic basis. The reactions of animals to light depend on a photochemical substance which may arise without reference to adaptation and occur in animals which pass their lives in total darkness in the mud or under the bark of trees. One is no more under the logical necessity of supposing that heliotropism can arise only in response to a need or under the guidance of a "directive force" than in the case of galvanotropism where no one would dream of invoking such conceptions. The reactions of a galvanotropic animal are as beautifully developed as any tropism although in nature such animals are never exposed to electric currents. Since a mechanistic explanation appears possible here why not in the case of other tropisms?

He emphasized the fact that many cases of "adaptation" may very well be the "preadaptations" of Cuénot, *i.e.* "adaptations" which arise before they can be of any use, which would seem to rule out a directive force. Thus many marine organisms die when placed in concentrated sea water but the fish *Fundulus* is an exception. If a portion of the ocean became landlocked so that the concentration of salts increased and all the fish except *Fundulus* died an observer might easily suppose that these fish had gradually become adapted to the more concentrated sea water.

Curiously enough his attempts to increase the natural resistance of *Fundulus* by placing it in sea water which gradually became concentrated by evaporation had little result.

He stressed the fact that in many other instances, including the famous case of blind fish in caves, there is evidence in favor of the idea that the supposed "adaptation" may have been a "preadaptation."

When adaptation really exists it appears in many cases as if it could be explained on a mechanistic basis without invoking a directive force, as, for example, when (in collaboration with Wasteneys) he brought about an adaptation of *Fundulus* to life at higher temperatures, a change which has many physicochemical analogues.

These examples may suffice to illustrate his point of view. He felt, however, that here as elsewhere quantitative experiments are a necessity and he therefore determined to undertake such experiments in studying regeneration. He proposed to ascertain whether in this field, long a stronghold of vitalism, careful measurements would reveal the rule of mechanism or the reverse.

Obliged to put the problem aside until he could discover suitable material he eventually found what he needed in the life plant of Bermuda (*Bryophyllum calycinum*). Its large leaves have numerous marginal indentations in which new plants arise when a leaf is separated from the stem and placed in a moist atmosphere. He made numerous experiments with this plant. He employed as a criterion of growth the dry weights of the parts studied. The result was not doubtful; whenever measurements could be made a machine-like regularity became apparent; for example, not only did two leaves detached from the same point on the stem produce the same dry weight of new buds and roots, but when a leaf was removed, a small piece of the stem being left attached to it, and the new growth was confined to the attached piece of stem, it was equal to the growth of new buds and roots on a similar leaf deprived of stem. He began a program of research on this basis but the work progressed slowly because a single experiment might require weeks and he would not have more going on than he could observe with minute care. Hence it happened that at the time of his death the program was only begun. He had, however, arrived at some tentative conclusions which, even when they were not novel, were of interest on account of their quantitative basis.

He concluded that the production of buds at one end of the stem and roots at the other was not due to differences in the "ascending" and "descending" materials, as Sachs and others had supposed; also that the formative material moves more readily toward organs where the most rapid growth occurs, which explains why those organs inhibit others which are growing more slowly; also that gravity may

cause sap to sink and so promote growth on the lower side. He likewise concluded that no "wound hormone" exists.

It is characteristic that he should so courageously attempt to place this difficult subject on a quantitative basis and to formulate it in mathematical terms.

An important episode which throws light on his habits of thought is his work upon the properties of proteins. His studies on the effects of ions had resulted in a series of articles in which he developed the idea (simultaneously with Pauli) that ions combine with proteins to form ion-protein compounds (70, 308). He also made the suggestion that pepsin owes its activity to its ionic state and that it is a weak base which becomes more ionized in acid solution and hence more active (trypsin being considered a weak acid). The idea had been published before, though without Loeb's knowledge. The suggestion was stimulating and led others to investigate the subject with the result that pepsin later came to be regarded as an amphoteric electrolyte (Michaelis) or as a monovalent anion (Northrop), trypsin being a monovalent cation (Northrop).

Carrying his studies on proteins as far as he thought that existing methods could give clear-cut results he turned aside to pursue certain other problems growing directly out of his work on ions, such as artificial parthenogenesis and antagonistic salt action.

But the fact that he laid them aside did not mean that they were out of mind. For nearly twenty years they remained in the background awaiting the opportunity which only a new method could furnish. One day, washing some eggs of *Fundulus* on a filter to free them from adhering salt solution, the idea occurred to him that he might treat proteins in the same way to get rid of the excess of substances which did not combine with them. He thereupon placed powdered gelatin in solutions of acids and bases, rinsed off the excess of solution on a filter, and determined how much remained in the gelatin, his preliminary assumption being that this represented the amount in actual combination with the protein. Thus a way seemed to be opened to determine whether proteins combined with these substances in definite proportions. Although he subsequently abandoned this method the fact remains that this idea was the starting point of his renewed activity in this field of work.

His experiments soon convinced him that the subject had fallen into confusion because of insufficient attention to the hydrogen ion concentration: methods of measuring and of controlling this had been developed since he had first attacked the subject and he now made good use of them, availing himself at the start of the assistance of Dr. K. G. Dernby. He had now found the needed clue and he set to work with characteristic energy.

The importance of the hydrogen ion concentration lies in the fact that in alkaline solutions the protein acts like an anion but in sufficiently acid solutions it behaves as a cation. At a certain hydrogenion concentration (the isoelectric point) these two actions are approximately equal. He found that gelatin at its isoelectric point (pH 4.7) is almost inert. Its combining power is so small that it can easily be freed from salts by bringing it to this point (a matter which certain industries later found to be of great practical importance). At this point its osmotic pressure, viscosity, power of swelling, and some other properties are at a minimum. On addition of acid or alkali these properties increase and by plotting them against the pH values characteristic curves are obtained.

The explanation of these curves came about in a very natural way. In order to measure the osmotic pressure of the solutions they were placed in bags of collodion, impermeable to gelatin but permeable to water and to salts. This created the condition necessary for a Donnan equilibrium and it became necessary to study the principle set forth by Donnan, particularly as previously applied by Procter and Wilson to the swelling of proteins. It was found that by means of the Donnan principle all these curves received a quantitative explanation: this was so complete that Loeb felt justified in saying that until an equally satisfactory theory could be found his explanation seemed bound to stand.

The Donnan principle (more properly called the Gibbs-Donnan principle) states that ions inside a membrane which are unable to pass through it affect the behavior of those that do, acting as if they attracted those of opposite sign (thereby increasing their concentration inside the membrane) and repelled those of the same sign (thus decreasing their concentration inside). It may be expressed by the equation:

$$C_i A_i = C_o A_o$$

in which C_i and A_i represent the concentrations inside the membrane of the cation and the anion respectively of a diffusible salt: C_o and A_o are the corresponding concentrations outside.

The fact that the Donnan principle applies indicates that the protein is present as ions (or charged particles acting as ions). At the isoelectric point the number of ions is at a minimum. When the solution is made more alkaline they increase in number just as if the protein were a weak acid: they also increase if acid is added instead of alkali, as if the protein were a weak base. The gelatin therefore acts as an amphoteric electrolyte, behaving as a cation below pH 4.7 and as an anion above this point. Assuming for convenience that the molecule has one acid and one basic group we should have at the isoelectric point $NH_2 - R - COOH$. On the addition of NaOH this would behave like a weak acid such as acetic acid and give sodium gelatinate, $NH_2 - R - COO^- + Na^+$ (which may be written $G^- + Na^+$). But if HCl were added the gelatin would behave like a weak base such as ammonia, giving gelatin chloride, $Cl^- + NH_3^+ - R - COOH$ (which may be written $Cl^- + G^+$).

It is therefore clear that the behavior of gelatin depends on its degree of ionization. The properties mentioned above have a minimum value at the isoelectric point because the ionization is at a minimum, and these values increase when acid or alkali is added because the ionization increases.

The Donnan principle leads us to expect that when protein is placed in a collodion sack which is permeable to water and to ordinary salts but not to the protein there will be a difference of potential between the inside and outside of the membrane (membrane potential). No one had succeeded in finding this but Loeb was able to demonstrate that it is present and that its magnitude is in accordance with the theory.

These facts are in harmony with the idea of Procter and Wilson that in the swelling of a gel each particle of protein acts very much like a collodion sack filled with a solution of protein and that the amount of swelling is proportional to the amount of pressure which would be produced in such a sack. In one case the molecules and ions of protein are kept together by the walls of the sack and in the other by their mutual coherence.

He concluded that the Donnan principle explains quantitatively some of the most puzzling peculiarities of proteins, such as the fact that, starting with the isoelectric point and adding acid or alkali, the osmotic pressure, viscosity, and swelling power increase up to a certain point and then begin to decrease. This depends on the sign and the charge of the cation of the alkali and on the anion of the acid which is added. These effects are diminished by neutral salts, the influence of the salt depending on the charge of the ion whose sign is opposite to that of the protein.

The presence in the solution of submicroscopic particles in addition to the gelatin ions and molecules introduces a complication but it is one which can be controlled and studied. It is evident that in so far as the gelatin forms particles it will behave as a colloid but in so far as it is in the form of molecules or ions it will behave as a crystalloid. But these molecules or ions will behave as colloids if prevented from diffusing (*e.g.* by means of a collodion membrane) and Loeb emphasized the fact that colloidal properties cannot be manifested unless diffusion is restricted by semipermeable membranes or by the coherence of the molecules to form particles. In this connection the semipermeable membranes of the living cell assume great importance.

He studied many other questions, such as the cataphoretic charge on proteins, which cannot be fully discussed here.

In view of his results Loeb felt obliged to reject many of the current conceptions regarding proteins, as, for example, the idea that the effect of acids, bases, and salts is due to adsorption and the theory that viscosity depends on the hydration of protein ions. He also concluded that under the conditions of these experiments the Hofmeister series did not apply. He pointed out the importance of the idea that proteins are amphoteric electrolytes and stressed the importance of quantitative methods of study, with careful control of the hydrogen ion concentration. He clearly indicated the significance of these facts and concepts for physiology.

His work was a powerful stimulus to research and is widely regarded as an immense simplification and clarification of the whole subject. He himself declared that his work was only a first approximation leaving much to be done to complete the picture.

It is of interest to note that just as the early distinction between

colloids and crystalloids had been replaced by the idea that the same substance may be in a cólloidal or a crystalloidal state, depending on the size of the particle, so Loeb substituted for this another conception, that of colloidal behavior, *i.e.* the same particles may behave as colloids or crystalloids depending on the presence or absence of semi-permeable membranes.

In the course of this work Loeb was struck with the fact that a collodion bag full of salt solution placed in contact with pure water may show a movement of water outward, instead of the inward movement which would be expected on a purely osmotic basis. This phenomenon (which is known as anomalous osmosis) had been previously explained as due to a difference in potential on the two sides of the membrane, the latter charged by the adsorption of ions. To Loeb however this explanation was not satisfactory and he began in characteristic fashion to resolve this complex problem into its component parts by setting up experiments in which each factor could be studied separately.

He recognized the fact that anomalous osmosis is much more marked in dilute solutions and that it makes a great difference whether the experiment is made with an ordinary collodion membrane or one which has been treated with protein. He summed up his observations in the following rules:

"1. Solutions of neutral salts possessing a univalent or bivalent cation influence the rate of diffusion of water through a collodion membrane, as if the water particles were charged positively and were attracted by the anion and repelled by the cation of the electrolyte; the attractive and repulsive action increasing with the number of charges of the ion and diminishing inversely with a quantity which we will designate arbitrarily as the 'radius' of the ion. The same rule applies to solutions of alkalies.

"2. Solutions of neutral or acid salts possessing a trivalent or tetravalent cation influence the rate of diffusion of water through a collodion membrane as if the particles of water were charged negatively and were attracted by the cation and repelled by the anion of the electrolyte. Solutions of acids obey the same rule, the high electrostatic effect of the hydrogen ion being probably due to its small 'ionic radius'" (328).

He showed experimentally that Rule 1 was valid whether the collodion membranes were treated with proteins or not but that Rule 2 did not apply to untreated membranes. Thus when solutions of salts with a trivalent cation were separated from pure water by a

protein-treated collodion membrane, water diffused rapidly from the solvent into the solution while no water diffused into the solution when untreated membranes were employed. Negative osmosis could be shown with acids only when the electrolyte was separated from pure water by a protein-treated membrane.

These seemingly paradoxical phenomena were explained by Loeb as due to the behavior of the proteins towards acids and alkalies. Untreated collodion membranes are always negatively charged in contact with pure water whether hydrogen ions or trivalent cations are present or not. Treated collodion membranes are also negatively charged on the alkaline side of the isoelectric point of the protein employed but positively charged when the protein is acid. This might be expected since in alkaline solutions the protein functions as the anion and in acid solutions as the cation. The anomalous behavior of trivalent ions was shown to be due to the formation of complex ions between the trivalent metal and the protein used to coat the collodion membrane. Salts with trivalent cations, such as $LaCl_3$, form with proteins complex ions which are positively charged but tetravalent anions, such as Na_4FeCN_6, yield complex ions which are negatively charged.

He further showed from experiments at different pH values that, due to the presence of protein in the membrane, a Donnan equilibrium was set up with the result that some of the acid is forced from the salt solution into the outer liquid which originally contained no salt. The difference in hydrogen ion concentration inside and outside of the membrane creates a potential difference.

A contributing factor is the diffusion potential (which would exist even though no membrane were present): this is apparently responsible for the fact that when the pH value is the same on both sides of the membrane (and lies on the acid side of the isoelectric point of the protein contained in the membrane) the rate of diffusion of negatively charged water into salt solution increases with the valency of the cation and diminishes with the valency of the anion of the salt. In the case of monovalent cations the diffusion of water into the salt solution was found to vary inversely as the relative mobility of the cations employed.

The distinct contribution of Loeb in the field of anomalous osmosis lies in the fact that his explanation does not involve adsorption.

In the midst of his research on proteins he was stricken down. Death came when he was actively engaged in what he regarded as the most fundamental investigation of his life. He himself said that it was the work with which he should have begun, since it was more logical to commence with the simpler systems found in colloids than with such conditions as exist in protoplasm. But indeed none could know better than he that the ways of research are not to be regarded as mere matters of logic.

III.

This brief sketch may serve to outline the development of his ideas. But since the man was greater than his work his achievement cannot be properly understood without some notion of his personality.

We must recognize that he was above all an idealist. Protected by academic life, and by a devoted wife who knew how to aid him in times of stress and encourage him during his hours of depression, he lived largely apart in a world of ideals. They wrought in him so powerfully that he spoke to his followers with prophetic fire. Their inspiration lured him on, dominating his life. He embodied Pasteur's profession of faith before the Academy, in the words now graven on his tomb: "Heureux celui qui porte en soi un dieu, un idéal de beauté, et qui lui obéit."

The austerity which goes naturally with high ideals, the temper of the aristocrat in the finest sense of the word, was his, but he had also a tender heart which felt the sorrows of all who suffered and his sympathy was always with the masses who struggle against oppression whether economic or spiritual.

We must also realize that he had the temperament of an artist, running the gamut of the creative imagination, its brooding depression, its rare exaltation. He knew the heights and the depths but not the happy mean of mediocrity. That nobility of soul which accompanies this temperament at its best was also his: a fine scorn of injustice, grossness, and all unbeautiful things.

The outstanding feature of his intellectual equipment was his creative imagination, implying prophetic vision, the intuitive and emotional urge of ideas which we call divination, the qualities that raise the seer above the common run.

With such a temperament intense mental effort may result in exhilaration rather than exhaustion. If this be called capacity for work we should realize that it is quite different from the capacity for doing disagreeable work. To him research was a joyous adventure, however much it involved that might be called drudgery.

It is no exaggeration to say that he lived in his work as do few men. It seemed as though his mind were continually occupied with his problems not only when awake but even during sleep when subconscious processes seemed to carry on with troublesome questions which might yield him a solution in the morning. When he reached a point where he was making no progress he turned to something else until these processes were readjusted and he could make a fresh start. He often found it advantageous to keep two or more pieces of work going on so that he could rest by turning from one to the other, as when he found recreation in working with *Bryophyllum* during his researches on proteins. His career illustrates the fact that continual concentration of mind (purely spontaneous, and very different from a forced concentration which cannot be long sustained) can produce an astonishing quickness of judgment, the ability to proceed with confidence when others find themselves at loss.

Fortunately his poetic imagination was associated with a keen critical sense. The more audacious the conception the more rigorous must be the proof. He would test and retest his conceptions and repeat his experiments over and over again. It is remarkable that so few of his observations of fact had subsequently to be modified. He published only a small part of his experimental work, and of the many suggestions that occurred to him few found their way into print. His students were often amused when he began to think aloud in the midst of a lecture, making and discarding one hypothesis after another for he had the rare gift of thinking while he spoke. He was wont to say "Nothing is so cheap as an idea." Indeed ideas came so rapidly that often he did not know which to follow. But when one had been selected he was not satisfied until he had thoroughly tested it.

He rarely published an observation without formulating a working hypothesis regarding the underlying causes. But he regarded such working hypotheses merely as temporary tools to be discarded when better could be found and he never hesitated to reject his own hypotheses when he could replace them by juster conceptions.

With this critical attitude toward his own work, which developed more and more as he grew older, it was natural that he should be as critical of others: but he shrank from giving pain and always hesitated a long time before publishing his criticisms. If attacked he proved himself a doughty antagonist.

The questions he put to nature were never dull and in consequence the answers he received were always interesting, sometimes startlingly so. He did not begin to work until he felt that he had framed the question properly. He assumed that in order to put an intelligent question to nature there must be a clear guiding principle. He did not believe in plunging blindly into the labyrinth. He was not satisfied until he had pondered on all the possibilities, both of attack and of interpretation, knowing that a bizarre suggestion is often the one that leads to discoveries. His method of approach was seldom conventional and the result was apt to be surprising. His colleagues were often astonished when he seized upon a subject from an entirely new angle. A scientist who had devoted much time and thought to formulating certain rules of scientific discovery exclaimed in disgust "He has no right to make such discoveries."

When the question had been formulated he recognized that the chance of a successful answer lay largely in the choice of material. In this respect he displayed great sagacity. It is said that when he began his work on tropisms he was found among the cases of the museum looking for animals that most resembled plants. True or not, the story illustrates his habit of mind.

His notion of biological research was simple: all the observed phenomena should be expressed in the form of equations containing no arbitrary constants. Anything short of this is to be regarded as merely preliminary. In attempting such a program the success of the investigator must depend on his capacity and courage, his choice of material, and the state of science, particularly on the state of physics and chemistry. He must know enough about organisms to be able to make a wise choice of material and thoroughly to understand the behavior of the form which he selects. He must be prepared to assist in clearing up the particular field of physics or chemistry which he needs to use as a tool, as Loeb himself illustrated in his work on colloids.

He felt that the biologist should aim at the same sort of control

over living matter that the physicist and chemist have over their material and that the best prospect of success lies in applying their methods to biology. His attitude may be illustrated by a quotation.

"Facts of this character should dispose of the idea that the organism as a whole does not react with that degree of machine-like precision which we find in the realm of physics and chemistry. Such an idea could only arise from the fact that biologists have not been in the habit of looking for quantitative laws, chiefly, perhaps, because the difficulties due to disturbing secondary factors were too great. The worker in physics knows that in order to discover the laws of a phenomenon all the disturbing factors which might influence the result must first be removed. When the biologist works with an organism as a whole he is rarely able to accomplish this since the various disturbing influences, being inseparable from the life of the organism, can often not be entirely removed. In this case the biologist must look for an organism in which by chance this elimination of secondary conditions is possible. The following example may serve as an illustration of this rather important point in biological work. Although all normal human beings have about the same temperature, yet if the heart-beats of a large number of healthy human beings are measured the rate is found to vary enormously. Thus v. Kőrösy found among soldiers under the most favourable and most constant conditions of observations —the soldiers were examined early in the morning before rising—variations in the rate of heart-beat between 42 and 108. In view of this fact, those opposed to the idea that the organism as a whole obeys purely physico-chemical laws might find it preposterous to imagine that the rate of heart-beat could be used as a thermometer. Yet if we observe the influence of temperature on the rate of the heart-beat of a large number of embryos of the fish *Fundulus*, while the embryos are still in the egg, we find that at the same temperature each heart beats at the same rate, the deviations being only slight and such as the fluctuating variations would demand.[9] This constancy is so great that the rate of heart-beat of these embryos could in fact be used as a rough thermometer. . . . .

"Why does each embryo have the same rate of heart-beat at the same temperature in contradistinction to the enormous variability of the same rate in man? The answer is, on account of the elimination of all secondary disturbing factors. In the embryo of *Fundulus* the heart-beat is a function almost if not exclusively of two variables, the mass of enzymes for the chemical reactions underlying the heart-beat and the temperature. By inheritance the mass of enzymes is approximately the same and in this way all the embryos beat at the same rate (within the limits of the fluctuating variation) at the same temperature. This identity exists, however, only as long as the embryo is relatively quiet in the egg. As soon as the embryo begins to move this equality disappears since the motion influences the heart-beat and the motility of different embryos differs.

[9] Loeb, J., and Ewald, W. F., *Biochem. Z.*, 1913–14, lviii, 179.

"In man the number of disturbing factors is so great that no equality of the rate for the same temperature can be expected. Differences in emotions or the internal secretions following the emotions, differences in previous diseases and their after-effects, differences in metabolism, differences in the use of narcotics or drugs, and differences in activity are only some of the number of variables which enter." (290, pages 299–302.)

The urge of his mind was to see each subject simply and as a whole. He was not content to pursue a special part of a problem without considering its relation to all the rest. Processes in particular animals must be compared with those of other animals, of plants, and of inorganic nature. Nor was he satisfied to find that they had something in common but he must work until its real nature was evident, until his idea of it was so clear and simple as to become a tool of precision and power. To achieve this it was necessary both to simplify and to generalize and these powers he possessed to an extraordinary degree.

It was sometimes said that he pictured his problems too simply and was satisfied with explanations too simple to correspond to reality. But this was an important factor in his success for it encouraged him to attack complicated problems and proceed as far as possible. If the point at which he stopped was not always as near to the ultimate solution as he himself thought this can in no way detract from the value of what he actually contributed.

All his experimentation bore the hall-mark of austere simplicity. It was a part of his temperament to distrust complicated apparatus. Few could devise such simple and decisive means of testing their hypotheses. He eliminated errors due to the variation in organisms by performing great numbers of experiments with innumerable controls, repeating again and again until the possibility of error seemed to be eliminated. He showed remarkable sagacity in choosing the material where life processes could be studied in a clear and simple way by using the methods of physics and chemistry and he had great skill in finding the procedure which would bring out the essentials of the phenomenon in question. He wasted no time in unprofitable experiments. If he could not find an organism which would give an unequivocal answer to the question he put the problem aside until a suitable organism should be found. Though he might wait for years he was prompt to act when the right material presented itself.

Courage played a great part in his success. He did not select problems because they were easy but because of their importance. That at the very outset he attempted to investigate the freedom of the will on an experimental basis illustrates this. With him one felt the power of a mind which gloried in difficult problems, with a confidence in its power to conquer that came from a long series of triumphs. It was a mind always alert, poised to turn easily in any direction, and operating with bewildering speed and certainty.

His courage sprang largely from his faith in the cause to which he consecrated his life: a conviction that mechanism could explain the most baffling mysteries. It almost approached a dogma and his zeal knew no limits. It was a militant faith calculated to move mountains and it grew firmer with each new discovery. If a philosophy be judged by its fruits his convictions justified themselves for they inspired him to attack apparently impossible problems with an audacity that was often justified by important discoveries. Can any one suppose that he would have discovered more if he had been a vitalist?

This magnificent faith and enthusiasm seemed at times to transfigure him so that it was not strange that young men followed him gladly. He always encouraged their efforts and was eager to help them. He had a truly lovable and sympathetic personality that drew men irresistibly. His teaching was inspiring and unforgettable. It was free from pedantry and pose because they were utterly foreign to his nature. He detested sham: and the ways of the politician were anathema to him. One felt instinctively that he cared only for truth and that in its quest he would spare no labor or sacrifice.

The eager, impatient student found in him a spirit zealous, quick, and full of youthful fire: and indeed his enthusiasm kept him always young. He lectured with a dramatic intensity which sprang from deep feeling. To an interested student he would pour forth his soul but he was little inclined to lure or drive an unwilling pupil. He could not sympathize with the idea that pedagogy consists in subduing the class to a state in which it can no longer resist instruction.

His intimate talks in the laboratory were at once the joy and despair of fellow workers. His mobile features, his expressive, eager eyes, alight with enthusiasm, were a fascinating study as he flashed from mood to mood, smiles and frowns following in rapid succession.

Quick to wrath, he was also quick to feel the folly of anger and in the midst of a tempest he would suddenly stop, then smile, and at length burst into laughter as the incongruity of the situation dawned upon him. And his laughter was without after-trace of anger, open, whole hearted, and reassuring

His sense of humor was extraordinary: he dearly loved a joke even at his own expense. When in the mood he was unsurpassable both for wit and humor. At such times he relaxed completely, and indeed these moments were almost his only relaxation. But they seemed to suffice and after them he would resume his toil wholly refreshed.

In conversation the emotional character of his thought, with its sudden flashes, might sometimes prove exhausting or even bewildering to more phlegmatic natures. A visitor to his laboratory was quite apt to leave in a somewhat breathless state. The rapidity with which ideas were suggested, examined, and rejected was often astonishing. But conceptions that survived were treasured, to be thought through, dreamed over, and worked at, under an emotional stress which is often evident in his writing.

This emotional urge seemed to be capable of lifting him above personal considerations to levels of objectivity not always realized by those who did not come into personal contact with him. And this seemed to him the true scientific attitude: it was not surprising that in dedicating one of his books (290) to Diderot he should quote the words of John Morley: "He was one of those simple, disinterested, and intellectually sterling workers to whom their own personality is as nothing in the presence of the vast subjects that engage the thoughts of their lives."

Often dogmatic in expressing his views, he was always open to conviction and would at once admit the correctness of an opposing view if the evidence offered were sufficient. His criticism of opponents involved no personal malice and if they were in trouble none could be readier with assistance and sympathy. Indeed he was continually going out of his way to help people who were almost unknown to him. This quality greatly endeared him to his students, who felt for him gratitude and trust as well as admiration.

It is difficult to understand how one absorbed in such great tasks could find time for so many acts of thoughtfulness: could allow himse

to be so continually interrupted by those seeking help. It is no wonder that all who knew him testify to his immeasurable kindness. What Roux said of Pasteur applies also to Loeb: "L'œuvre . . . . est admirable, elle montre son génie, mais il faut avoir vécu dans son intimité pour connaître toute la bonté de son coeur."

The range of his reading was indeed a continual marvel. Scientific books and periodicals of all kinds were eagerly devoured and with unflagging interest he followed the newer developments of sociology, politics, and belles lettres. He could get the gist of an article very quickly and his astonishing memory seemed never to let anything slip. He sometimes quoted a remark of Sachs: "All originality comes from reading," meaning that it is necessary to be familiar with what is known in order to strike out in new directions.

This breadth of knowledge made it natural for him to utilize in his work recent advances in other fields of science. Thus he took the idea of tropisms and of heteromorphosis from botany: he applied to biology the theories of dissociation and osmotic pressure which resulted in the discovery of artificial parthenogenesis and antagonistic salt action. And to the very end of his life he kept in touch with recent progress in physics and chemistry and found application for much of it in his own studies. In his hands this cross-pollination of the sciences produced excellent fruit.

His multiplicity of learning was correlated by a synthetic imagination, an instinctive ability to unite harmoniously the diverse elements of different disciplines. He seemed at home in many fields and passed without effort or hesitation from one to another. He mingled the best elements of French and German culture; he successfully combined physical and chemical methods in the solution of his problems; he used in a masterly way the methods of the exact sciences to deal with vague and mystical biological concepts.

In all this he was aided by circumstances. His youth was a time of "Sturm und Drang" in the physiological sciences, when new wine was being put into old bottles, and the great impetus given to physiology by Claude Bernard and Johannes Müller was felt by a host of keen young workers of unusual ability and enthusiasm. At that time, too, the youthful science of physical chemistry was making extraordinary strides. Loeb appeared at the right moment to take advantage of

these remarkable circumstances and he utilized them with astonishing skill.

Such are some obvious aspects of this many-sided man, superficial features easy to recognize: but indeed to know his mind and heart is another matter.

Here we may perhaps pause to ask ourselves, How are we to remember him? He was an idealist, sympathizing keenly with all suffering, consecrating his gifts to humanity, finding in every discovery a weapon against superstition: a scientist with an artist's soul, emotional, intuitive, creative: a thinker, strangely original, born to blaze fresh trails and teach new doctrines with a prophet's zeal: and a dreamer, regarding the world of life with the poetic insight of a seer, and seeking, with creative imagination rarely equalled, to sweep aside its mystery and set free the mind of man.

"And he being dead yet speaketh." His visions that have made others see visions, his ideals that quicken the heart of youth, cannot but continue to shed inspiration, in circles that widen more and more; and in shaping the soul of the future he may serve humanity more than he dared to dream.

JACQUES LOEB

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